U.S. Department of Energy
Energy Efficiency
and Renewable Energy
Bringing you a prosperous future where energy
is clean, abundant, reliable, and affordable

Federal Energy Management Program

Introduction to
Renewable Energy Technologies

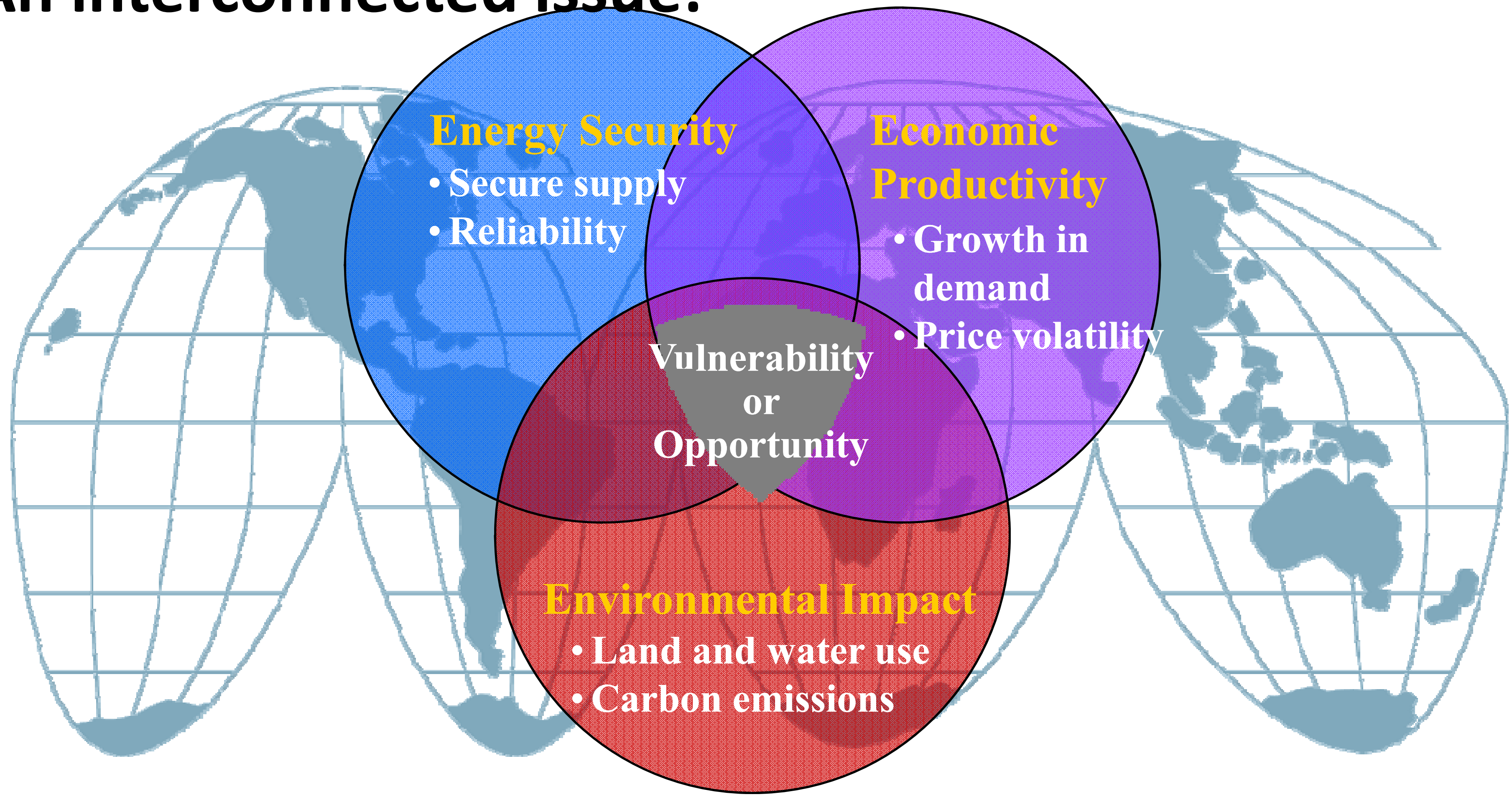
Course Objectives

- To provide an overview of renewable energy technologies
- To establish a foundation for implementing renewable energy projects at your Federal site.

Course Overview

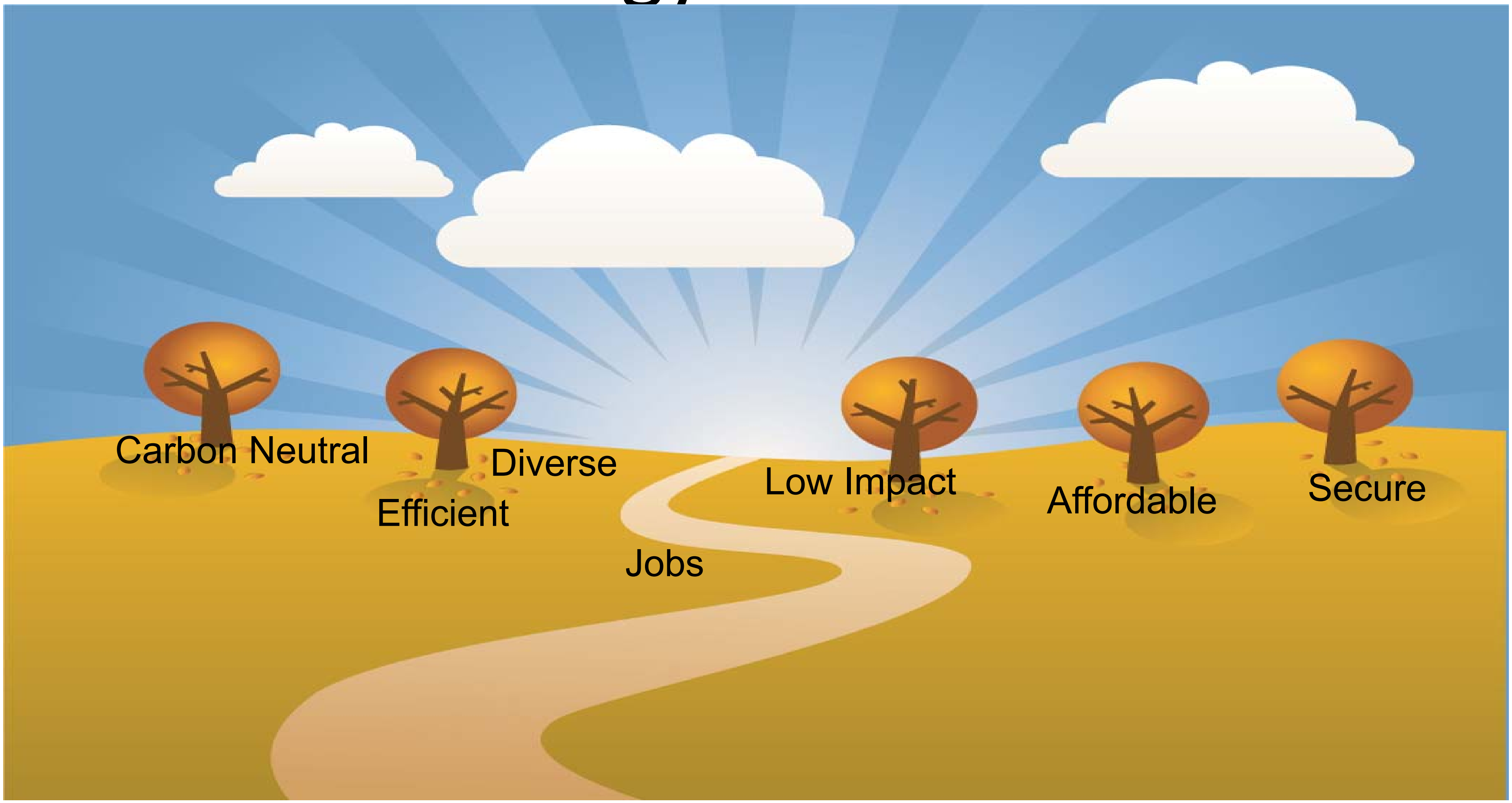
- Motivations for Renewable Energy
- Discussion of Renewable Energy Technologies:
  - Site consideration, resource maps
  - Technology overview, schematic
  - Costs
  - Case Study
  - Frontiers of research
- Information Resources

An interconnected issue:



Must address all three imperatives

Renewable Energy on the Horizon.



Motivations for Renewable Energy

- Energy Cost Savings ($/year)
- Avoid cost of infrastructure (power line extension, upgrade)
- Reduce Environmental Emissions (tons CO_2/year)
- Reduce volatility (Fuel adjustment charge)
- Hedge against rate increases (%/year)
- Fuel supply shortage/interruption
- Redundant energy supplies
- Employ local trades for install and O&M
- Balance-of-trade issues

Photovoltaics

Wind Power, Ocean

Solar Water Heating

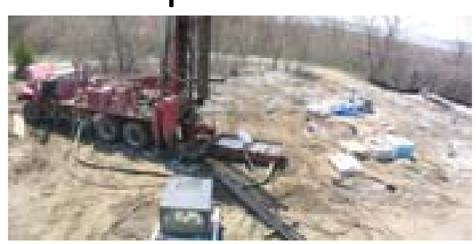
Solar Vent Air Preheat

Concentrating Solar Heat/Power

Biomass Heat/Power

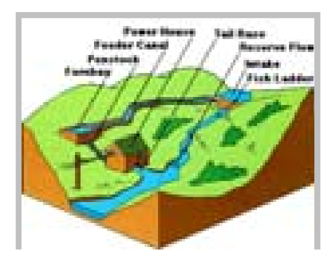
Daylighting

Ground Source Heat Pump



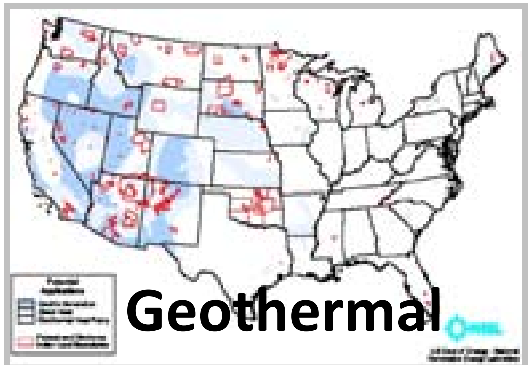
Landfill Gas

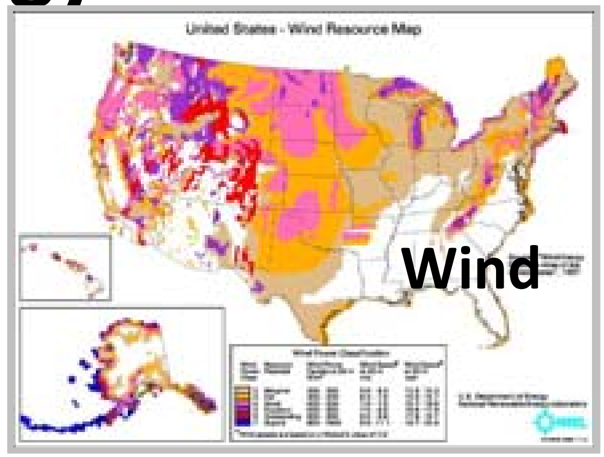
Small Hydro

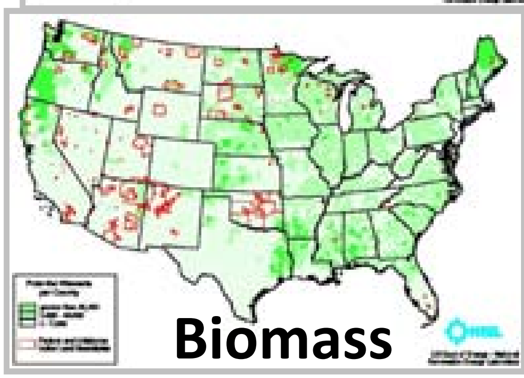


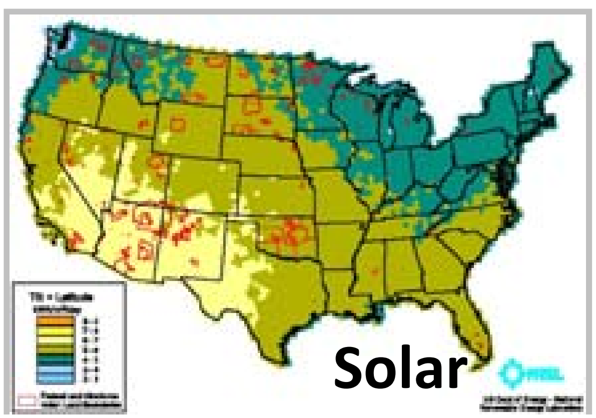
U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

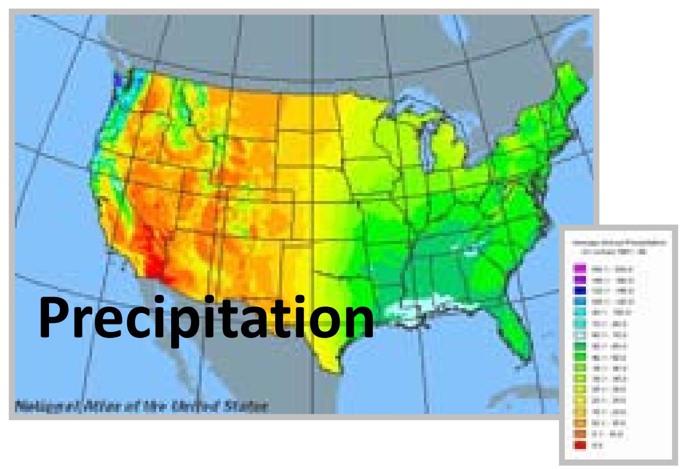
Renewable Energy Resources









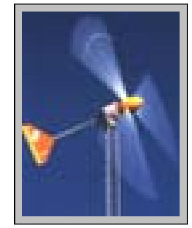


Renewable Technology Applications

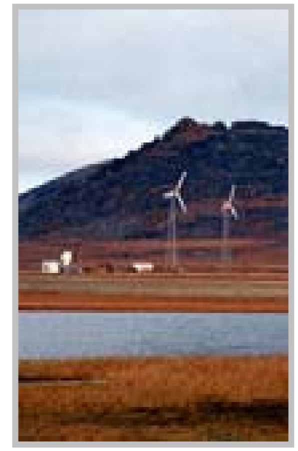
Remote Homes

Small Modular Power

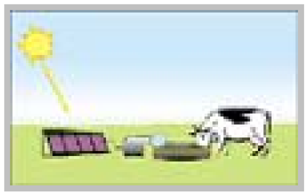
Small Wind



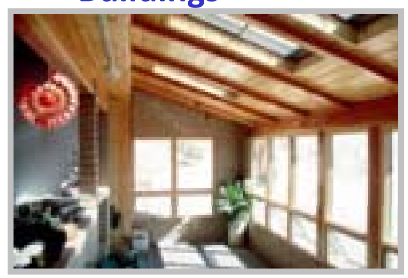
Diesel Hybrids



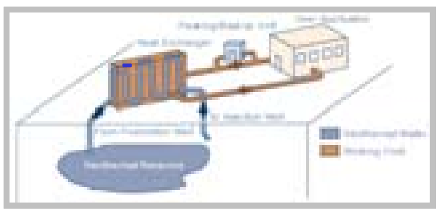
Stock Watering



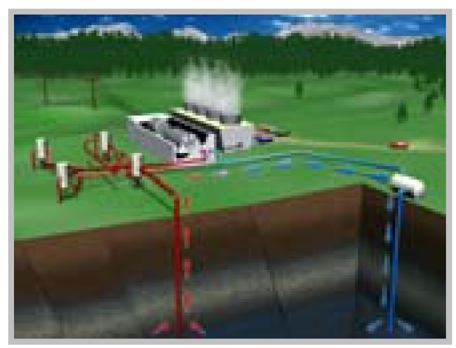
Buildings



Direct Use



Utility Power



Process Heat

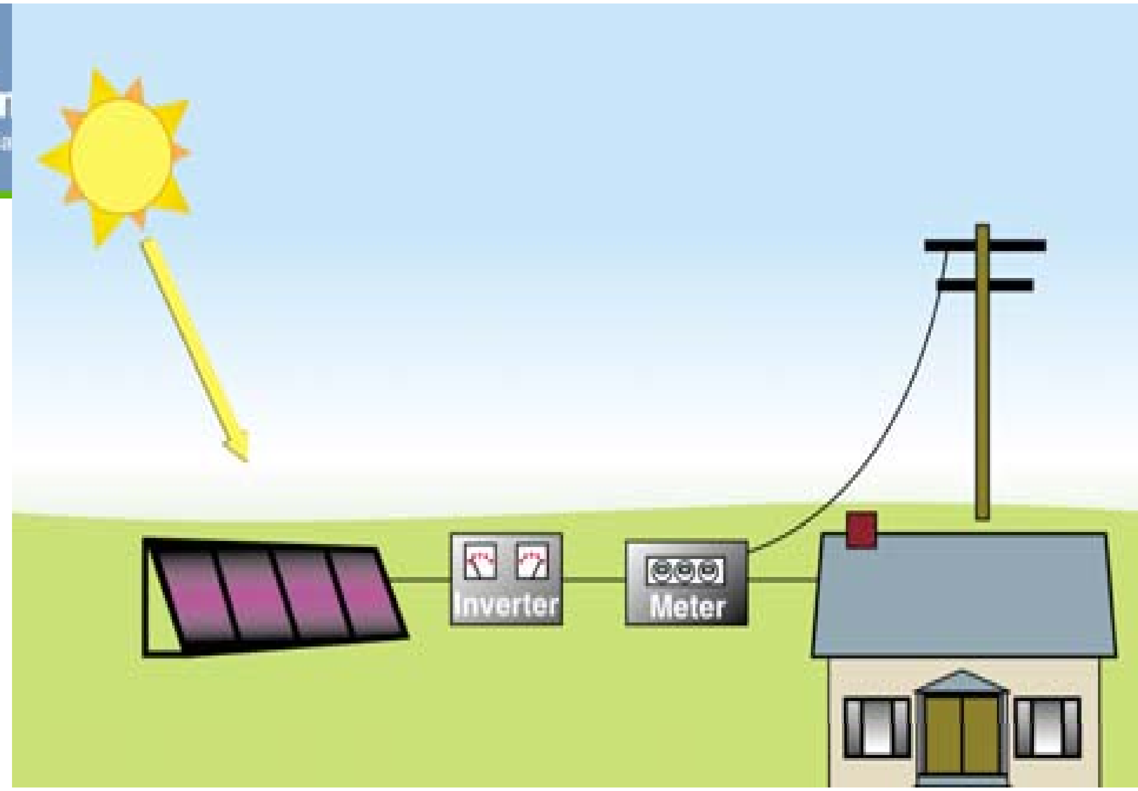
RE viability depends on:

- Your cost of energy
- Your local Renewable Energy resources
- Technology Characteristics
  - Cost ($/kW installed, O&M Cost)
  - Performance (efficiency)
- State, utility policies (interconnection, net metering charge structure)
- State, Utility and Federal Incentives
- Economic Parameters (discount rate, escalation rates)
- Your agency's policies and Mandates

Solar Photovoltaics (PV)

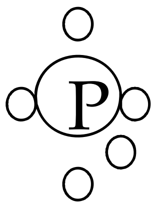
4 kW; WAPA, Loveland CO; amorphous thin fim

PV Technology Overview

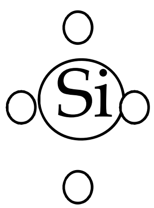


- Direct conversion of sunlight into DC electricity
- DC converted to AC by inverter
- Solid-state electronics, no-moving parts
- High reliability, warranties of 20 years or more
- PV modules are wired in series and parallel to meet voltage and current requirements

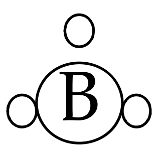
The Photovoltaic Effect



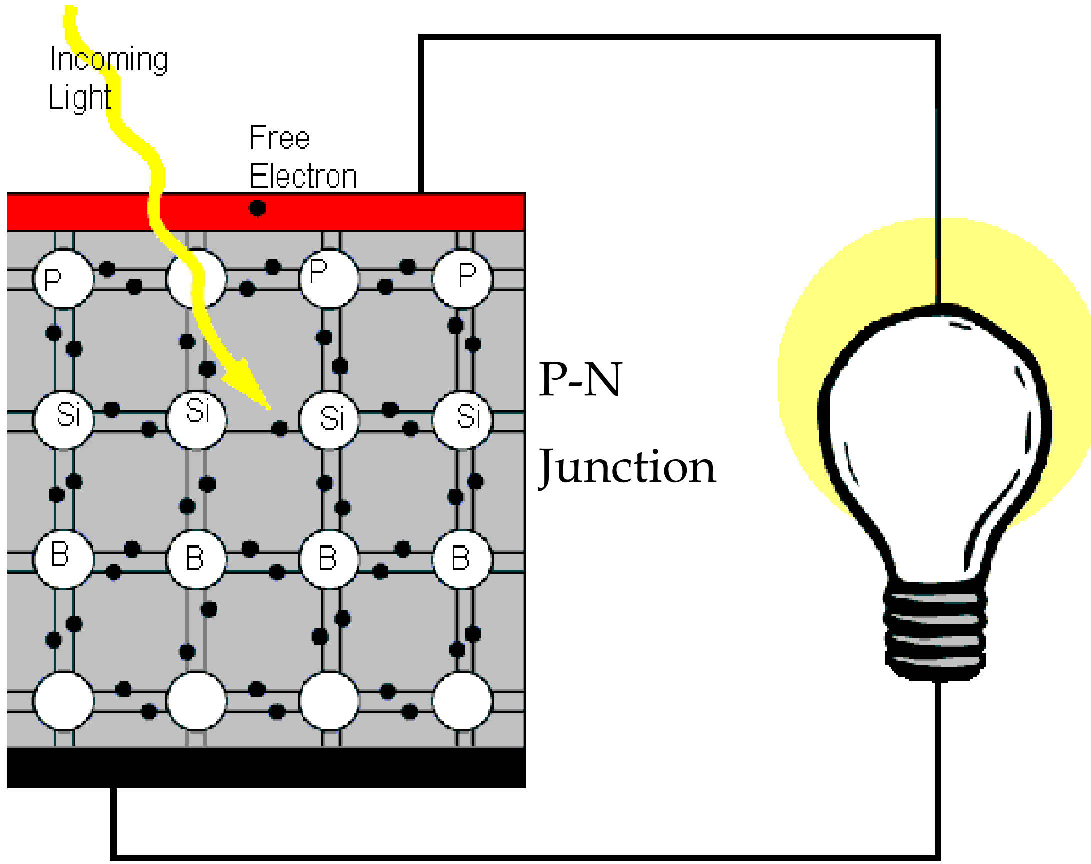
Phosphorous: 5 valence electrons



Silicon: 4 valence electrons

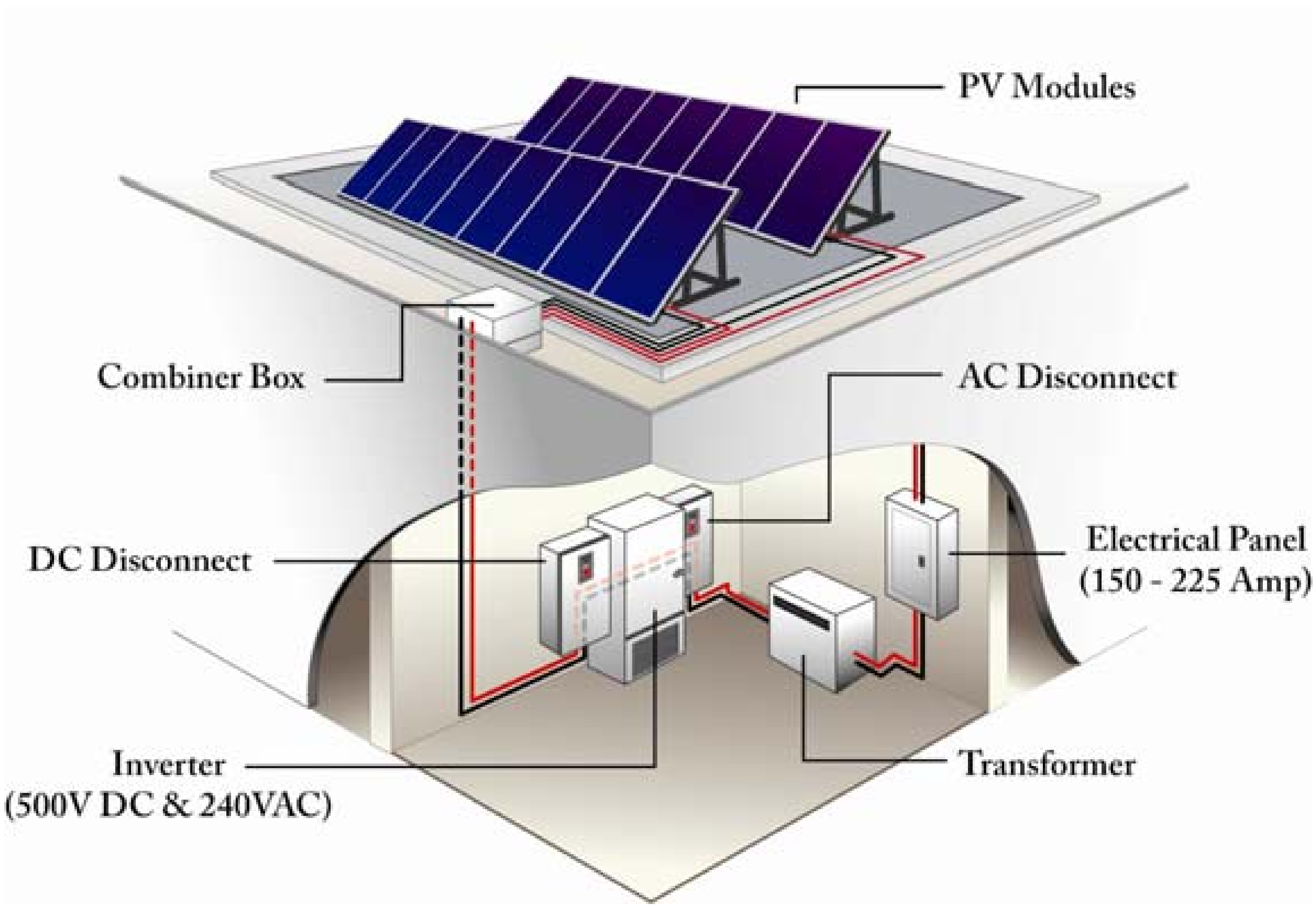


Boron: 3 valence electrons

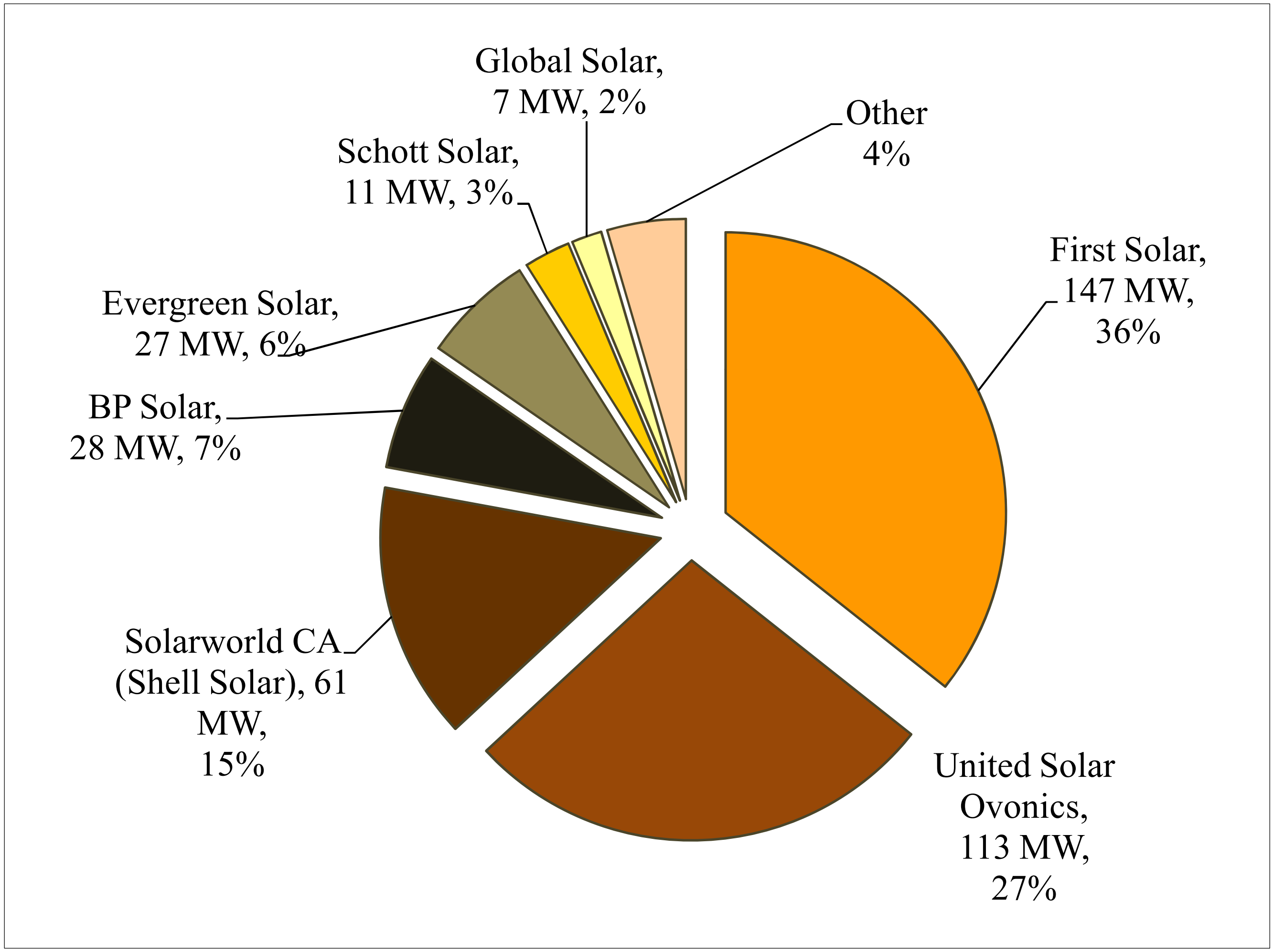


No material is consumed and the process could continue indefinitely

Photovoltaics System (grid connected)



2008 U.S. PV Manufacturers

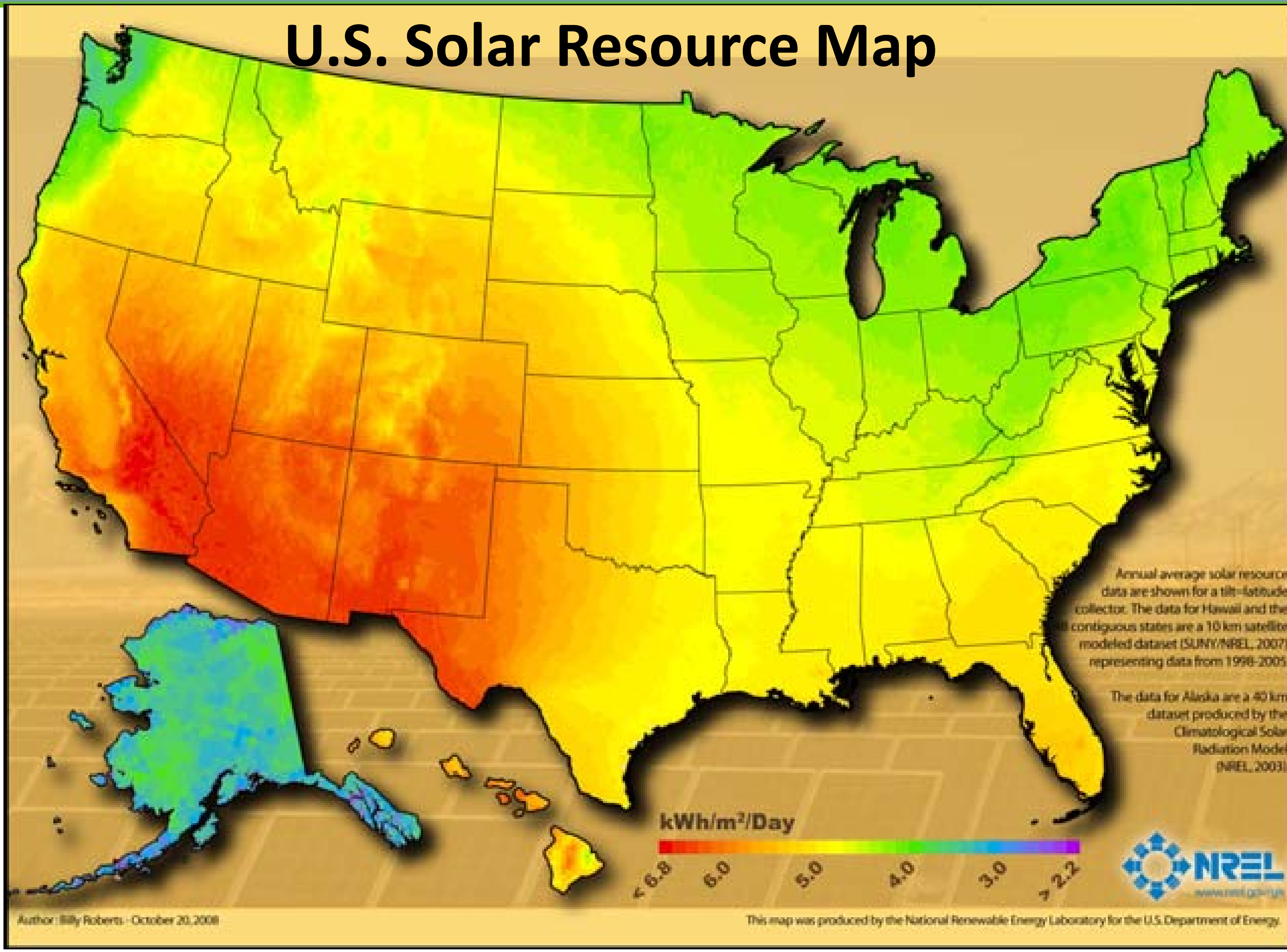


Sources: PV News, April 2009; First Solar website

PV Installation Considerations

- Panel installation on south-facing, un-shaded area
- Install on ground, roof, pole, carport, etc
- Panel tilt
- Tracking vs. Fixed
- Utility grid connection or stand-alone ('off the grid')
- Battery storage needed for off-grid operation

U.S. Solar Resource Map



States Leading Solar Energy Development

PV Cumulative Capacity (2008, MW)	
1 California	528.3
2 New Jersey	70.2
3 Colorado	35.7
4 Nevada	34.2
5 Arizona	25.3
6 New York	21.9
7 Hawaii	13.5
8 Connecticut	8.8
9 Oregon	7.7
10 Massachusetts	7.5

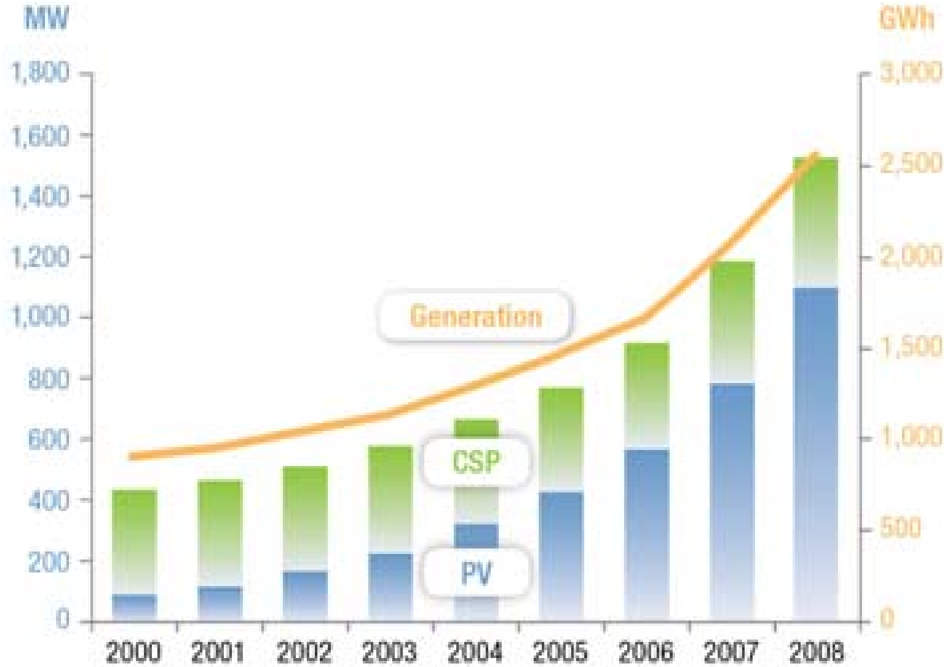
PV Annual Capacity Additions (2008, MW)	
1 California	178.7
2 New Jersey	22.5
3 Colorado	21.7
4 Nevada	14.9
5 Hawaii	8.6
6 New York	7.0
7 Arizona	6.4
8 Connecticut	5.3
9 Oregon	4.8
10 North Carolina	4.0

CSP Cumulative Capacity (2008, MW)	
1 California	354
2 Nevada	64
3 Arizona	1

Source: Larry Sherwood/IREC

Note: All installments equal 1% or less of electricity generation in states.

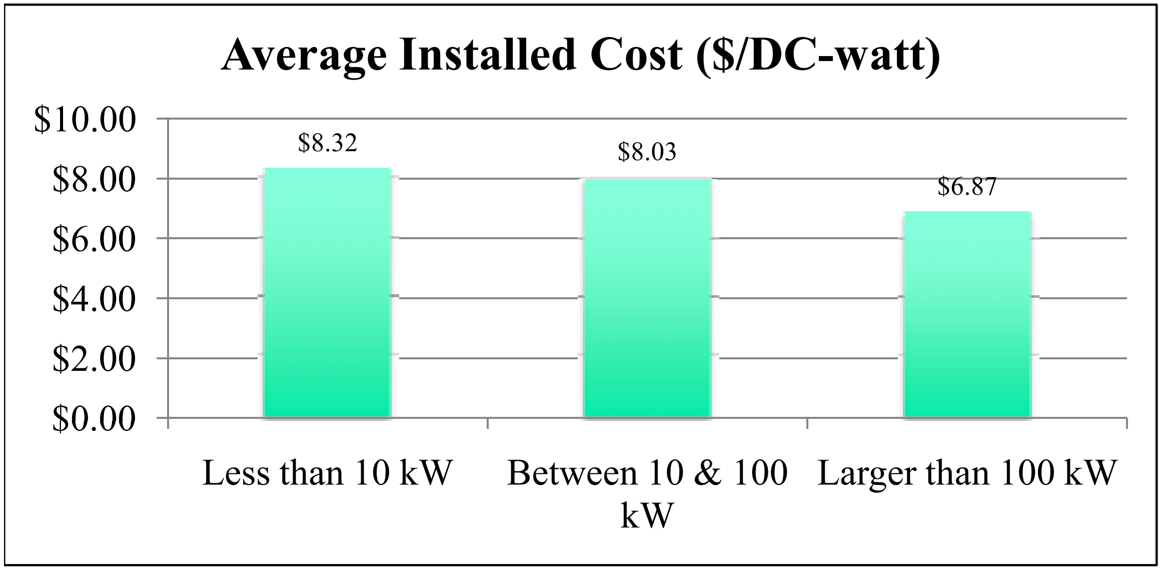
U.S. Total Installed Solar Energy Nameplate Capacity and Generation (PV and CSP)



	U.S. Solar Energy Generation (Million kWh)	U.S. Solar Energy Capacity (MW) and % Increase from Previous Year			
		PV*	CSP	Total	Increase
2000	909	85	354	439	4.3%
2001	952	112	354	466	6.2%
2002	1,021	156	354	510	9.4%
2003	1,132	226	354	580	13.7%
2004	1,267	312	354	666	14.8%
2005	1,444	424	354	778	16.8%
2006	1,670	566	355	921	18.4%
2007	2,133	771	419	1,190	29.2%
2008	2,662	1,106	419	1,525	28.2%

Sources: Larry Sherwood/IREC, Greentech Media
Note: Generation numbers calculated from installed capacity using a 18% capacity factor for PV and 25% capacity factor for CSP.
* Includes on- and off-grid capacity.

PV Cost, O&M, and Efficiency



PV System Type	Annual O&M Cost as a Percentage of Installed Cost
Ground Mounted - Fixed	0.17%
Ground Mounted - Tracking	0.35%

Efficiency= power out/power in

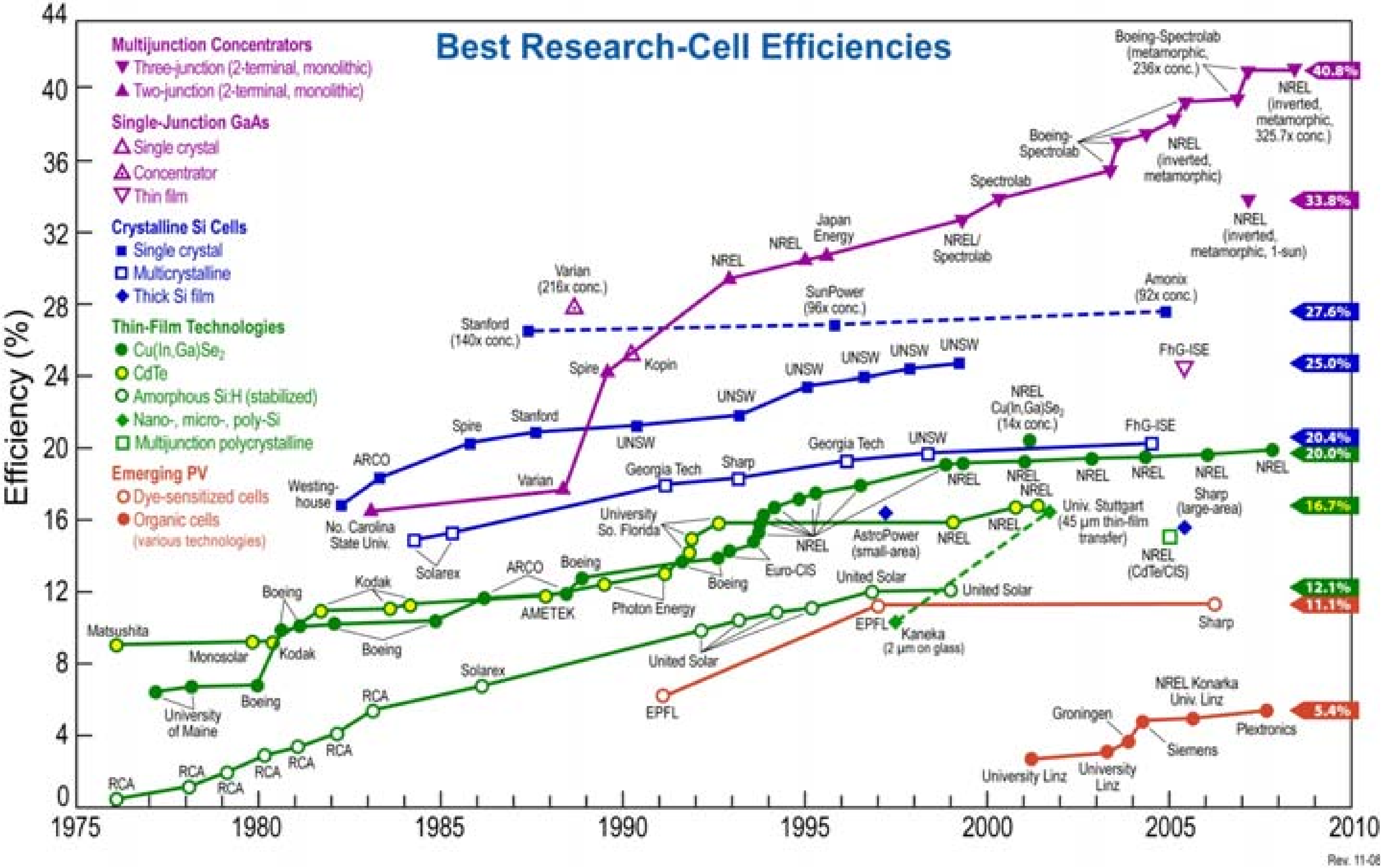
Module Efficiencies	Single Crystal	14-19%
	Multi Crystal	13-17%
	Thin Film	6-11%
Balance of System Efficiency		77%

Efficiency versus Size

- 1 kW of 15% eff. crystalline 71ft^2
- 1 kW of 9.5 % eff. amorphous 99ft^2
- 1 kW of 19.3% eff. hybrid 55ft^2

Veterans Administration Jerry L. Pettis Memorial Medical Center in Loma Linda, CA

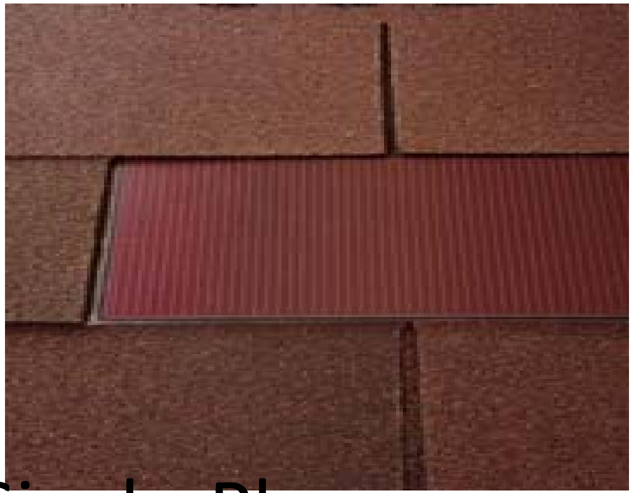
- 309 kWdc
- 1,584 Sanyo 195-watt PV modules
- SunLink racks minimum roof penetration.
- Advanced Energy Solaron 333kW inverter
- Feasibility Study by NREL estimates:475 MWh/year delivery; $60k/year savings; $2.9million cost without any incentives
- Procured off GSA Schedule for complete PV systems.


Best Research-Cell Efficiencies
Efficiency (%)
Multijunction Concentrators
Three-junction (2-terminal, monolithic)
Two-junction (2-terminal, monolithic)
Single-Junction GaAs
Single crystal
Concentrator
Thin film
Crystalline Si Cells
Single crystal
Multicrystalline
Thick Si film
Thin-Film Technologies
Cu(In,Ga)Se2
CdTe
Amorphous Si:H (stabilized)
Nano-, micro-, poly-Si
Multijunction polycrystalline
Emerging PV
Dye-sensitized cells
Organic cells
(various technologies)
Boeing-Spectrolab (metamorphic, 236x conc.)
NREL (inverted, metamorphic, 325.7x conc.)
NREL (inverted, metamorphic)
NREL (inverted, metamorphic, 1-sun)
Varian (216x conc.)
Stanford (140x conc.)
SunPower (96x conc.)
Amonix (92x conc.)
NREL Cu(In,Ga)Se2 (14x conc.)
Univ. Stuttgart (45 µm thin-film transfer)
Kaneka (2 µm on glass)
AstroPower (small-area)
Sharp (large-area)
NREL (CdTe/CIS)
NREL Konarka Univ. Linz
40.8%
33.8%
27.6%
25.0%
20.4%
20.0%
16.7%
12.1%
11.1%
5.4%
1975
1980
1985
1990
1995
2000
2005
2010
Rev. 11-08

Building-Integrated Photovoltaics

Glazing

Shingles



Standing Seam

Single-Ply

Solar Hot Water

Solar Thermal Applications

Low Temperature

- Swimming pool heating

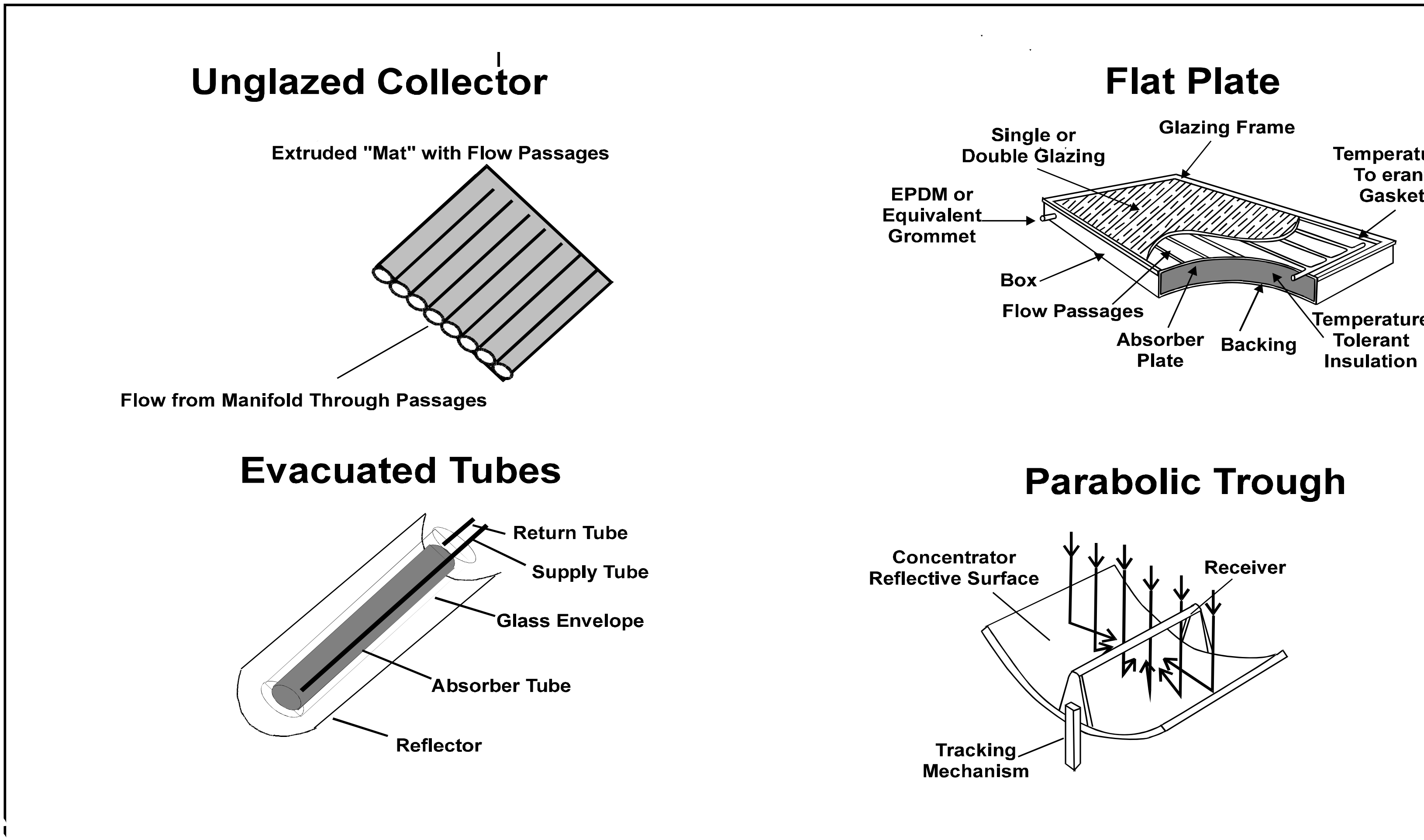
Medium Temperature

- Domestic water and space heating
- Commercial cafeterias, laundries, hotels
- Industrial process heating

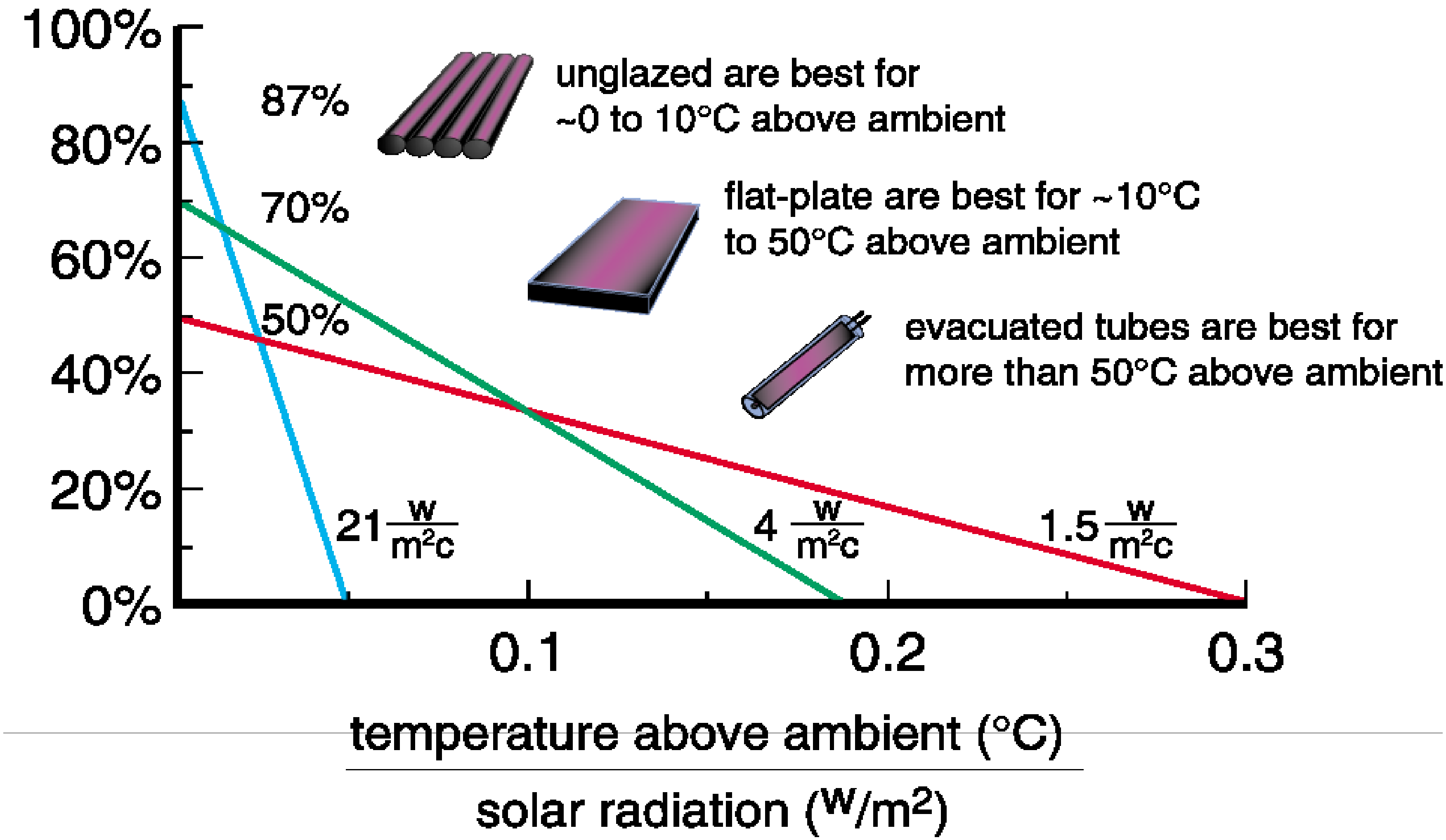
High Temperature

- Industrial process heating
- Electricity generation

Solar Thermal Collectors

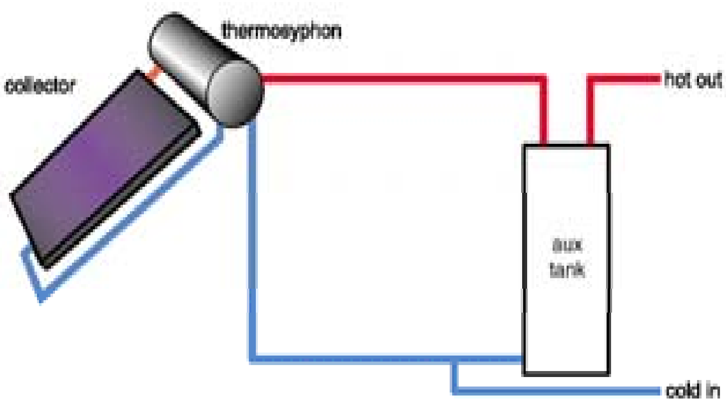


Which is best depends on temperature…

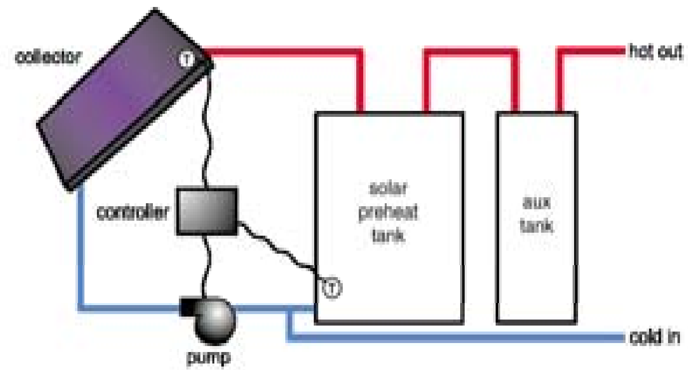


Best schematic depends on climate and application.

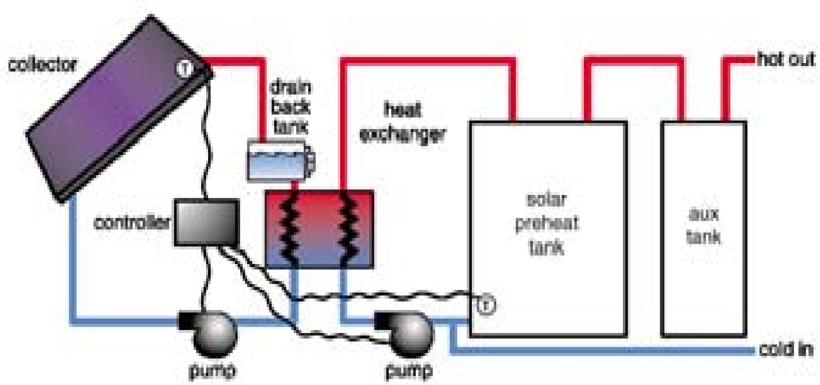
Thermosyphon



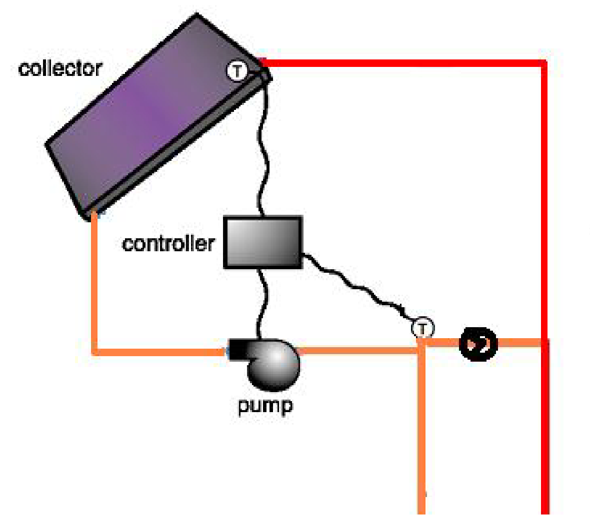
Direct Active



Indirect Drain Back

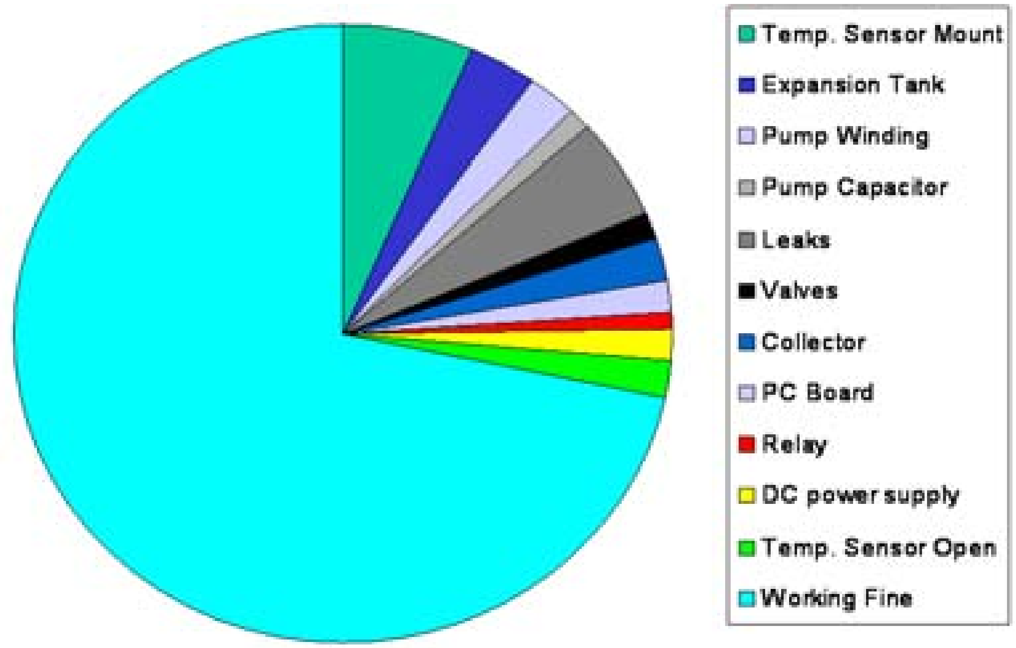


Recirculation Loop



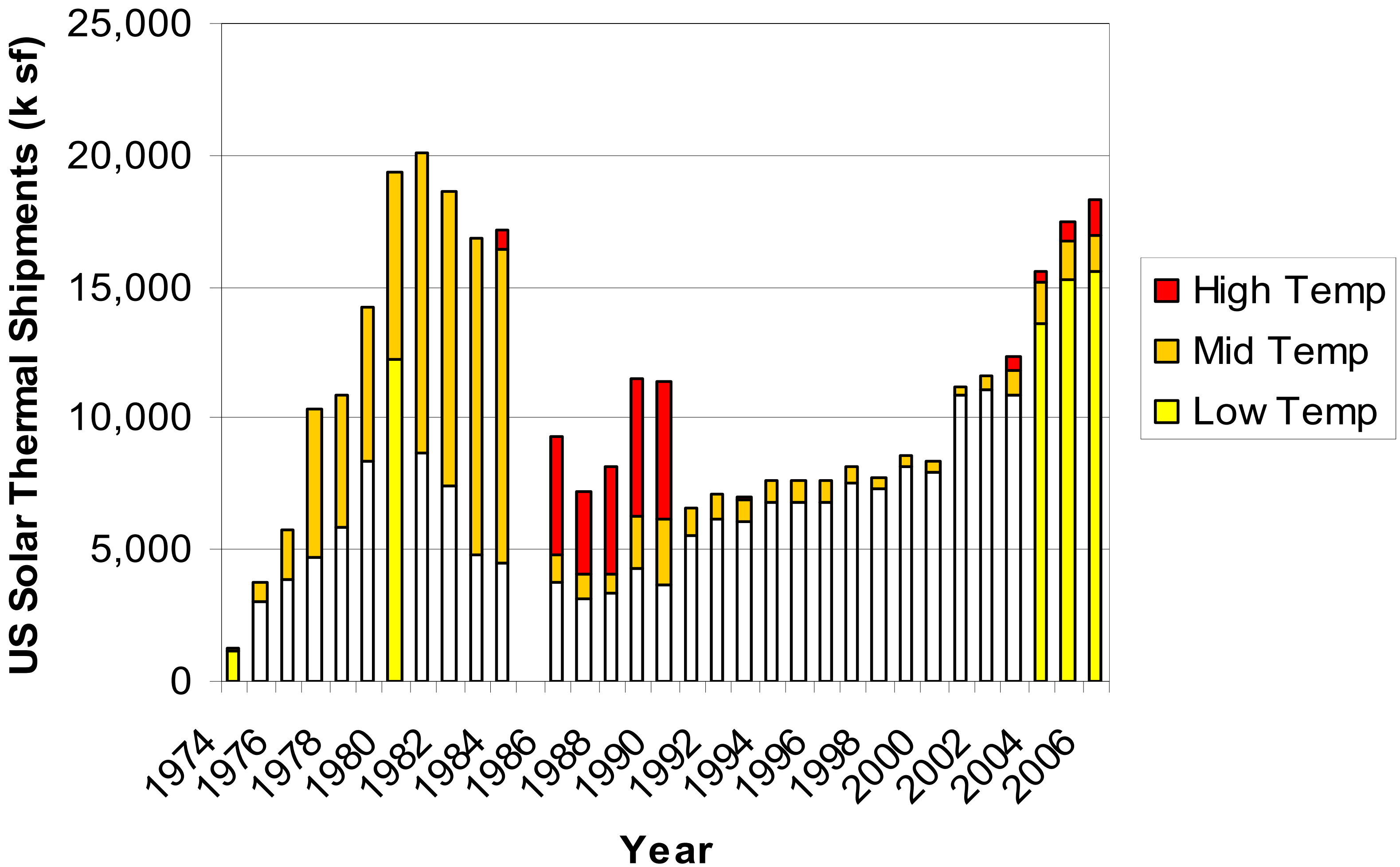
Solar Hot Water System Cost and Common O&M Requirements

Installed costs:
- \$600/ m^2 for large systems
- Over \$2,000/m^2 for small isolated systems
- \$1400/ m^2 ~ average



O&M Survey of 185 Solar Hot Water Systems

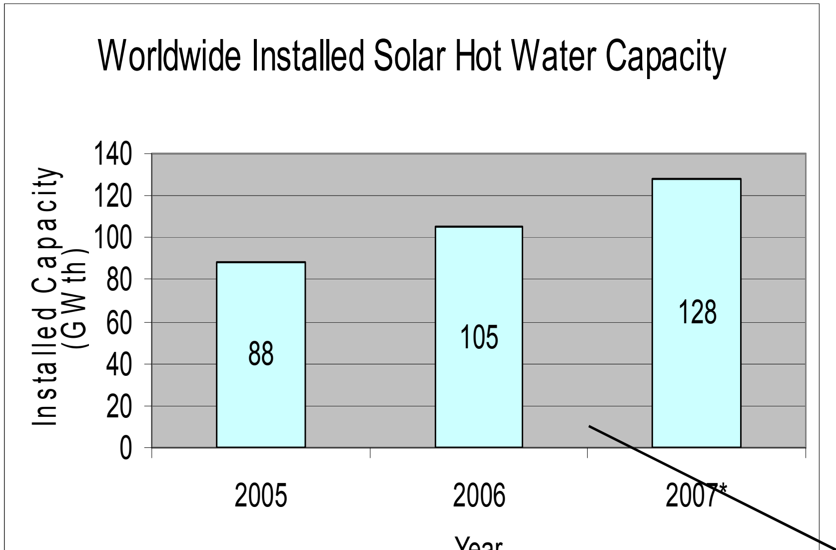
Solar Hot Water Heating Capacity and Trends



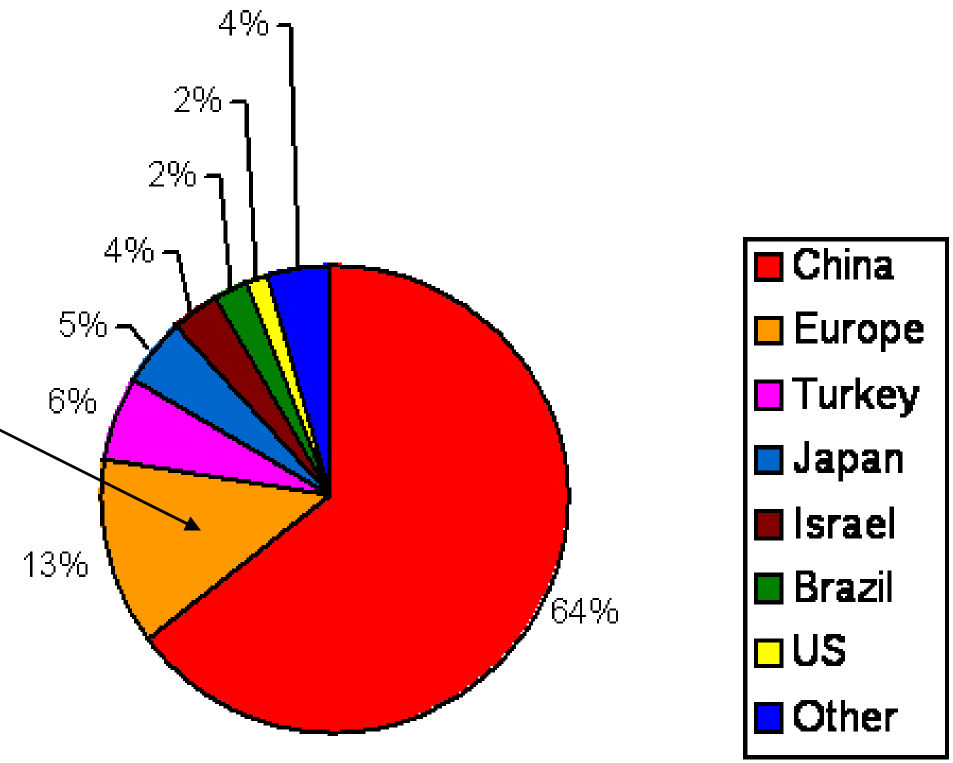
- US over 1 million systems in use

Source: EIA 2003, 2006 Data

World Solar Hot Water Market Share



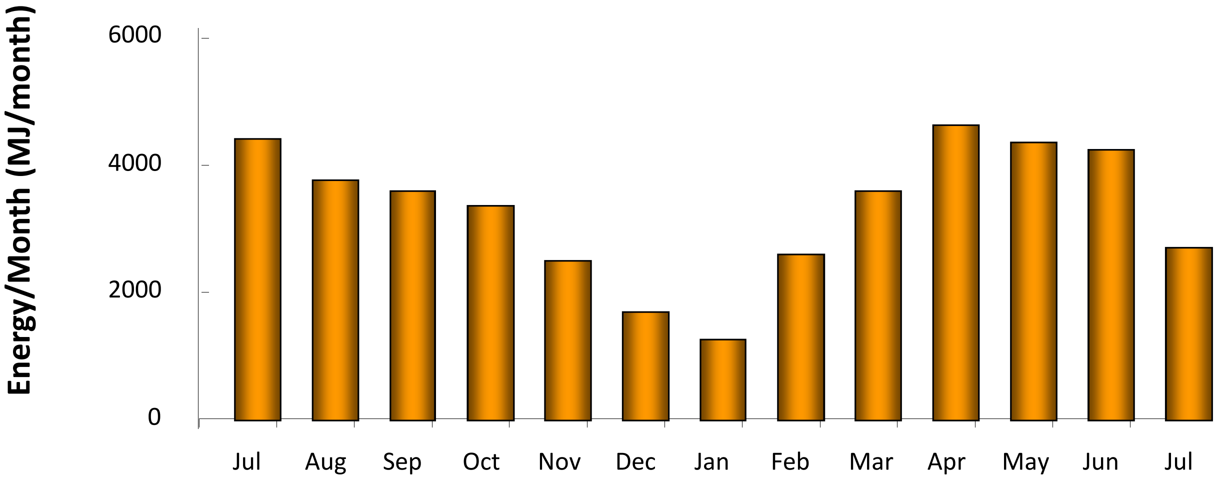
* 2007 data is estimated



Share of Total Installed Capacity Up to 2006 (105GW$_{th}$)

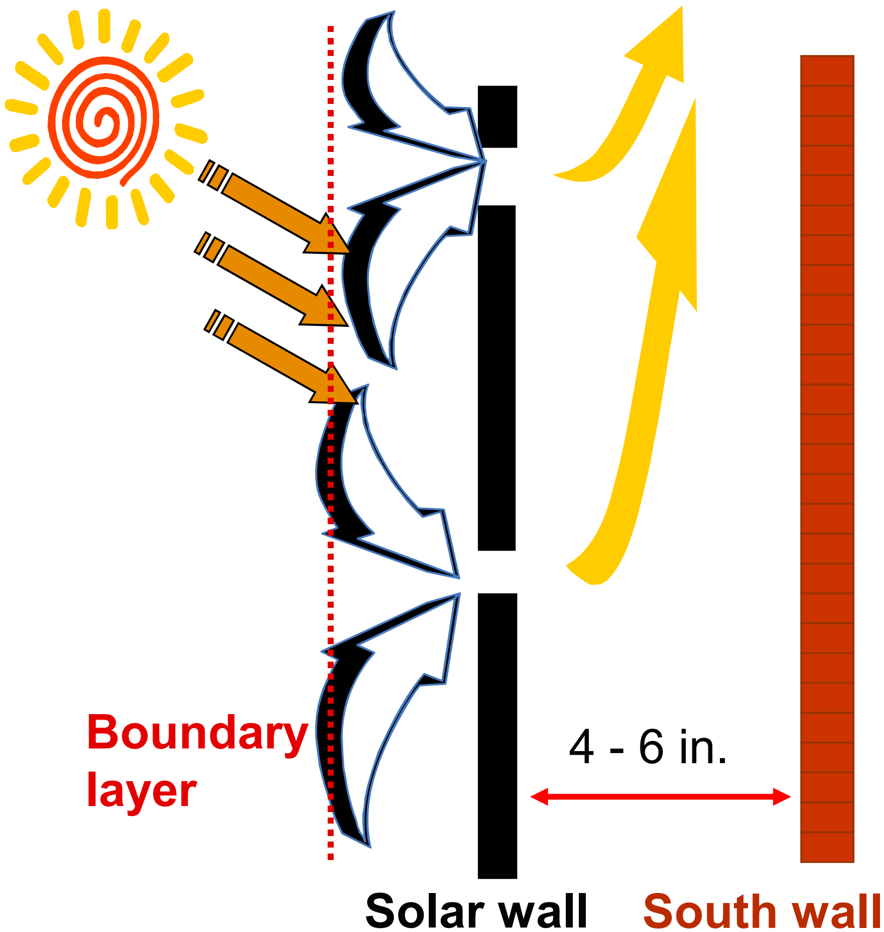
Solar Water Heating Case Study: Social Security Administration Building (Philadelphia, PA)

- Reheats recirculation loop
- 180 evacuated heat-pipe collector tubes
- 27 m2 gross area
- Cost $37,500
- Delivers 38 GJ (36 million Btu)/year
- Installed 2004



Solar Ventilation Air Preheating

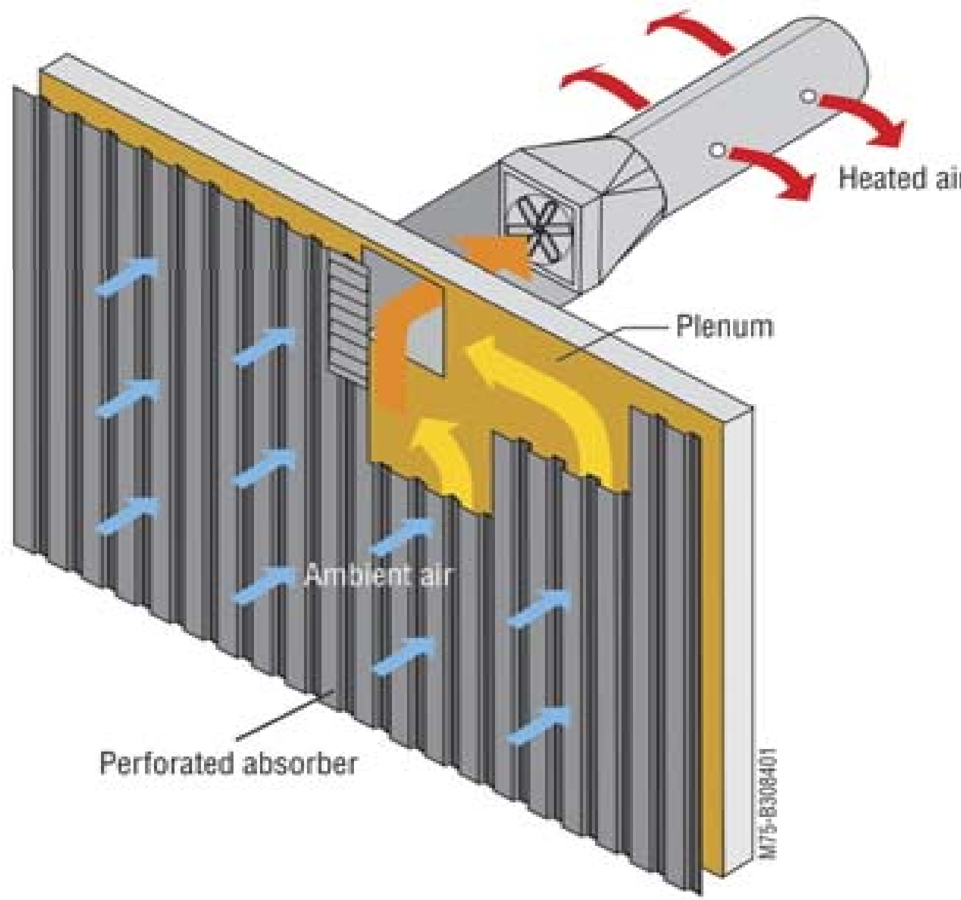
Transpired Solar Collector Technology Overview

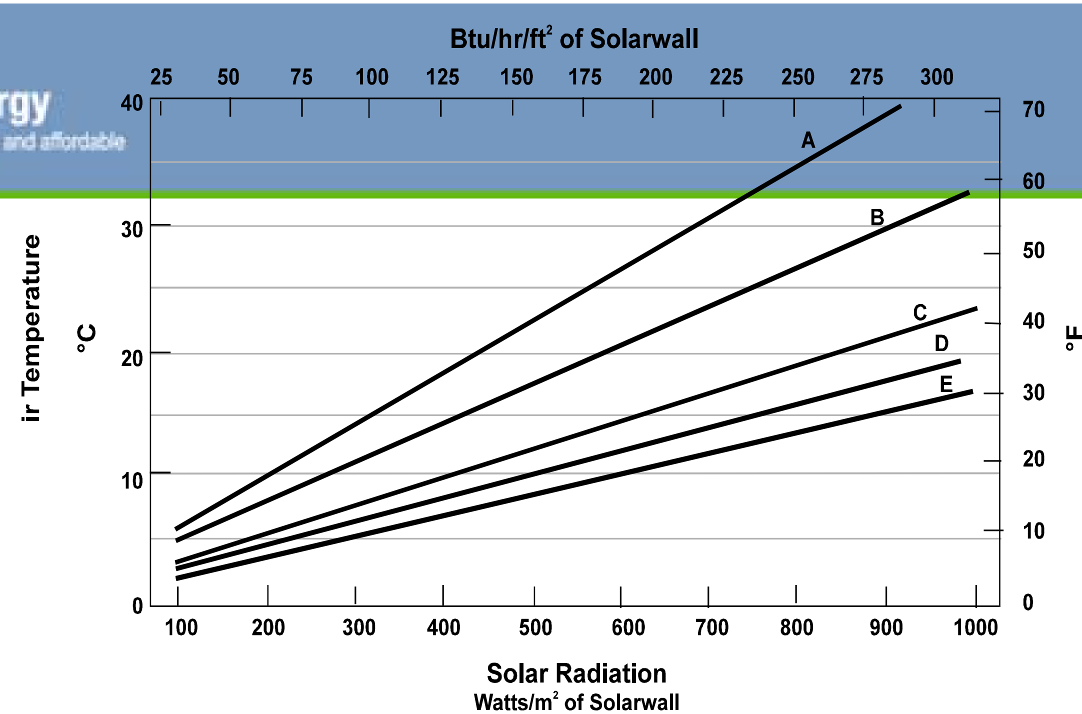


- Sun warms the collector surface
- Heat conducts from collector surface to thermal boundary layer of air (1 mm thick)
- Boundary layer is drawn into perforation by fan pressure before heat can escape by convection

Solar Ventilation Air Preheating System Components

- Transpired solar collector
  - Perforated sheet of corrugated metal
- Air distribution
  - Ductwork, fan and bypass damper
- Controls
  - Temperature and timeclock, or EMCS





(A) 1.0 cfm/ft^2 (0.005 m^3/s/m^2) (B) 2.0 cfm/ft^2 (0.01 m^3/s/m^2) (C) 4.0 cfm/ft^2 (0.02 m^3/s/m^2) (D) 5.4 cfm/ft^2 (0.027 m^3/s/m^2) (E) 7 cfm/ft^2 (0.035 m^3/s/m^2)

Perforated Collector

Wall Installation

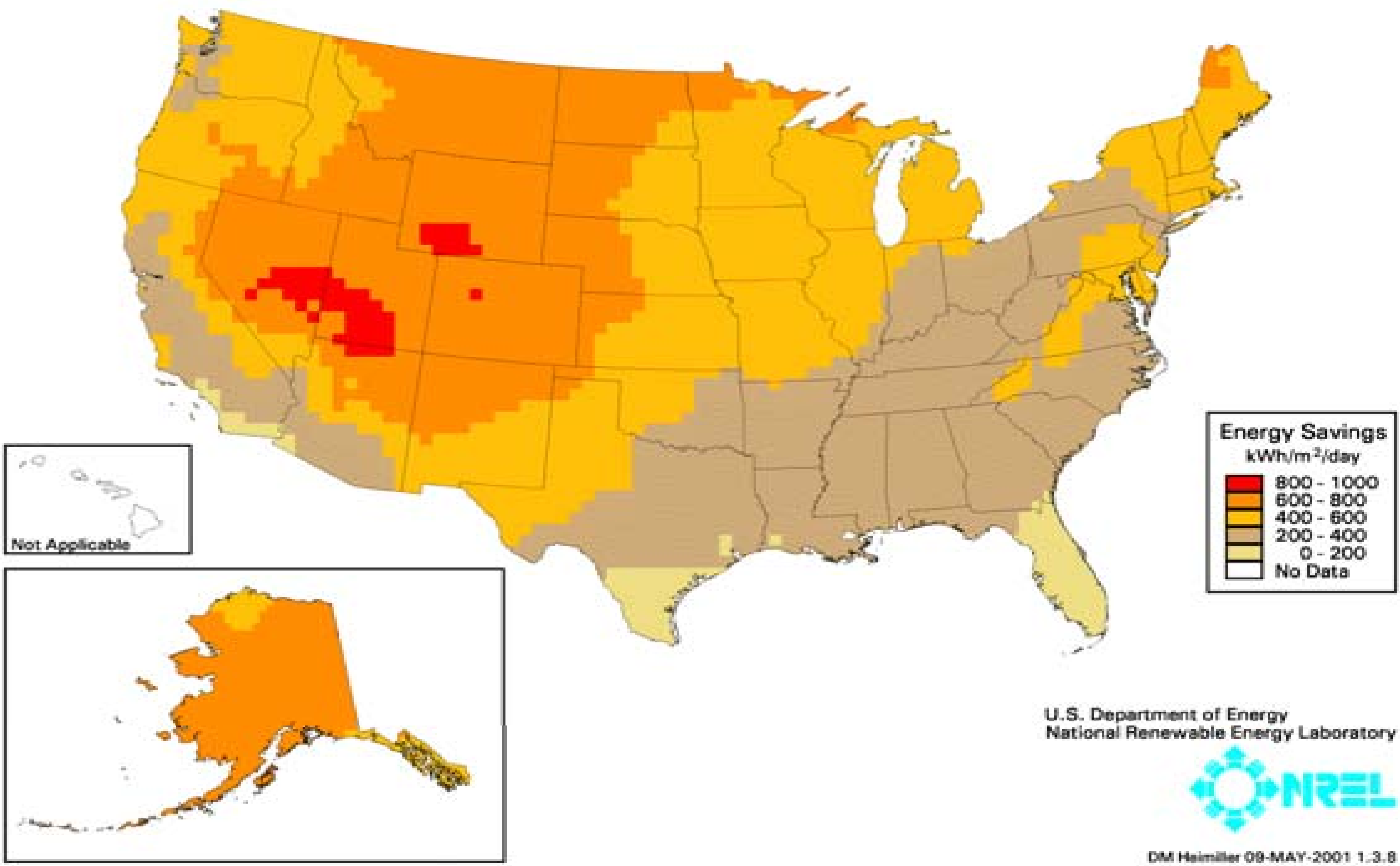
Bypass Damper

Solar Ventilation Air Preheating Applications

- Preheating outdoor ventilation air
  - Hazardous material storage
  - Maintenance
  - Laboratory
  - Industrial operation
  - Recreation facility
- Process air heating
  - Crop drying

Solar Ventilation Air Preheating Energy Savings

Energy Savings Utilitizing Solar Vent Preheating Technology



Solar Ventilation Air Preheating Costs

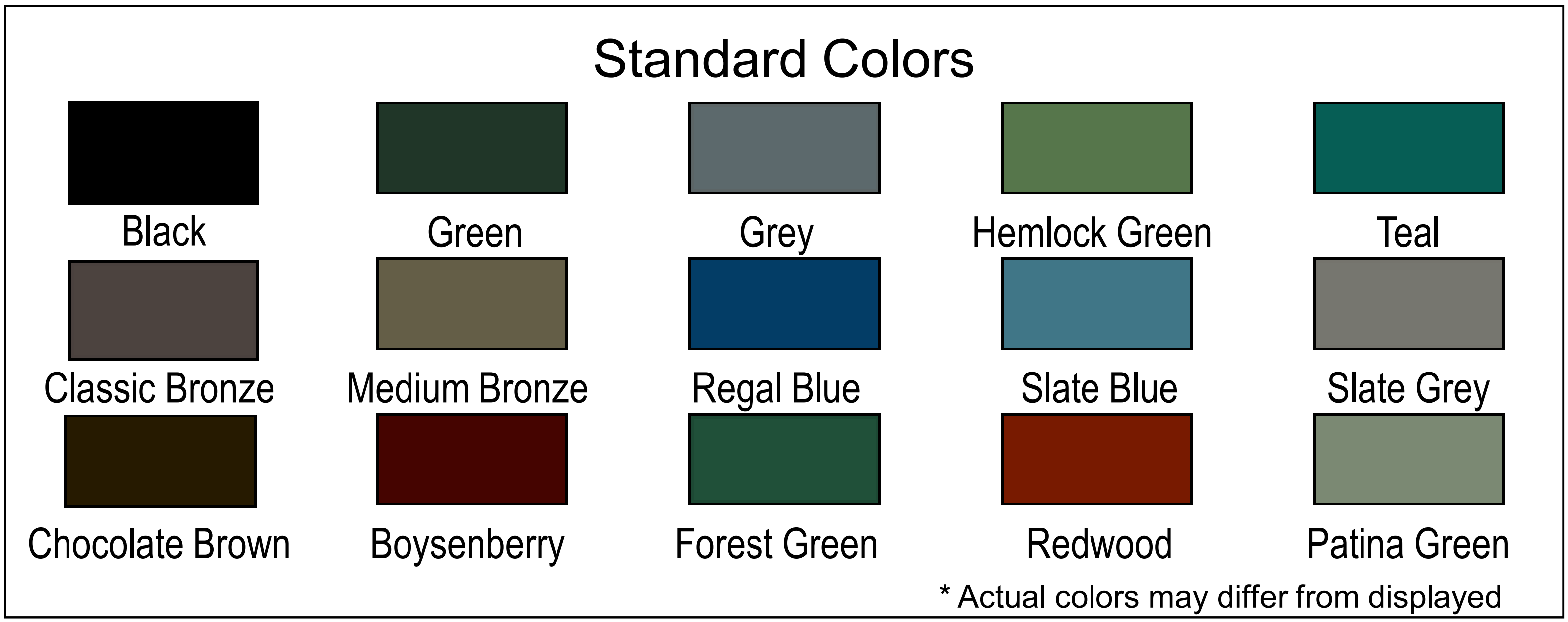
Installation Costs in Retrofit Applications

• Absorber	$14.50/ft^2
• Supports, Flashing, Etc.	$ 7.50/ft^2
• Installation	$ 4.00/ft^2
• Other Costs	$ 4.00/ft^2
• Total	$**30 - 40/ft^2**

Solar Ventilation Air Preheating Case Study: EPA Lab (Golden, CO)

- Hazardous material storage building
- Installed in 2001
- 296 sf, 2000 cfm
- 58% measured efficiency
- Saves 60 Mil Btu/yr and $450/yr natural gas
- Payback = 13 years

What's new in Solar Ventilation Preheat?...Colors!



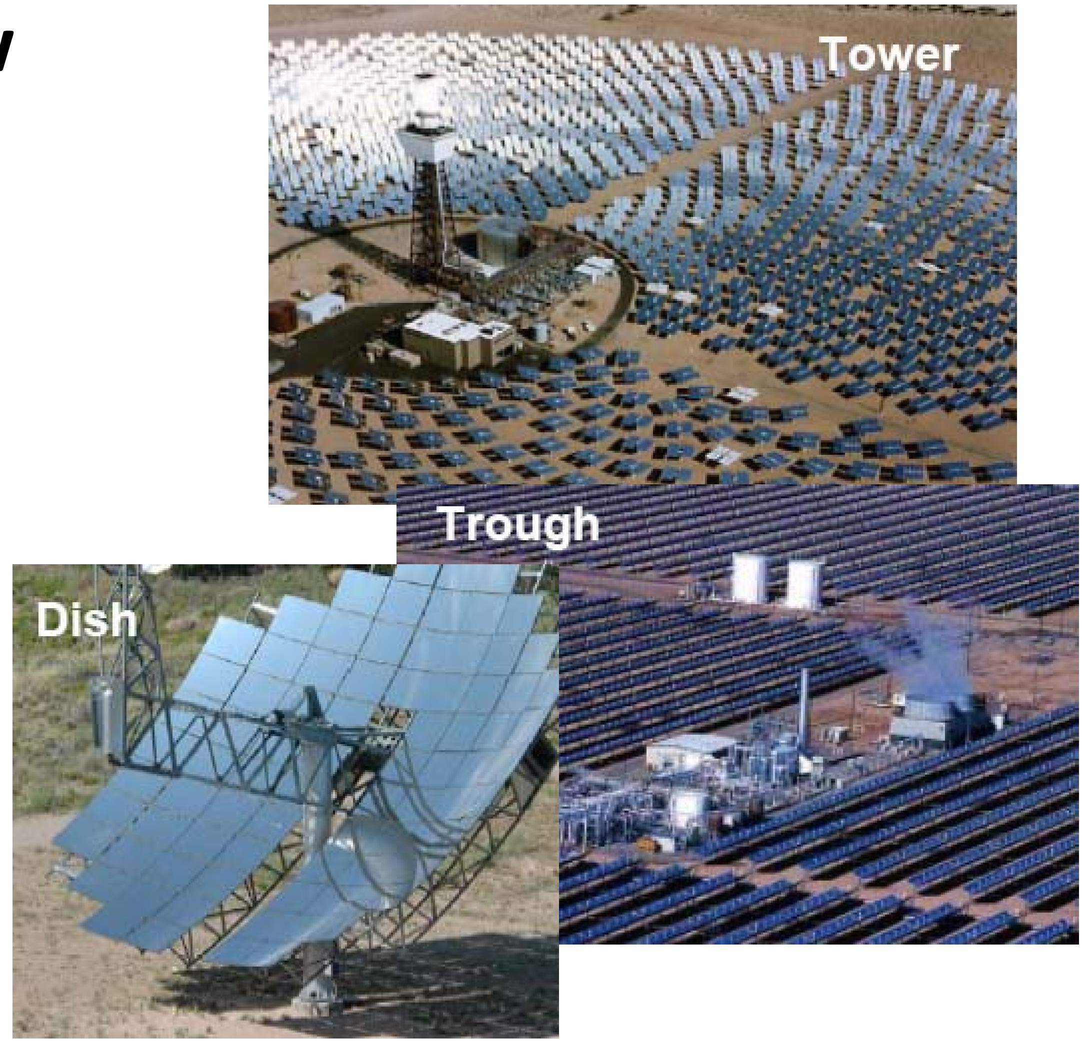
* Actual colors may differ from displayed colors

Concentrating Solar Power (CSP)

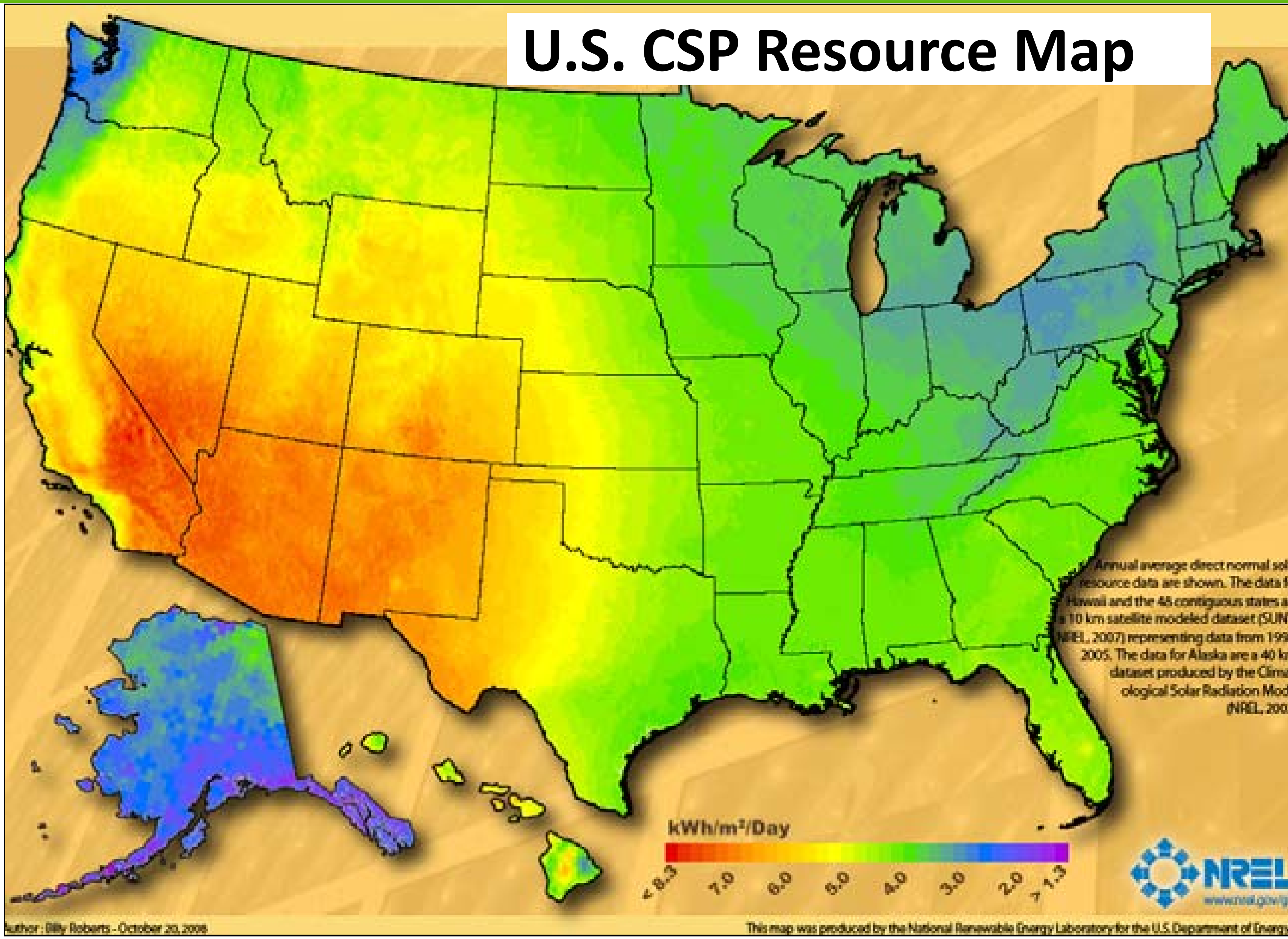
Concentrating Solar Power Technology Overview

Mirrors are used to reflect and concentrate sunlight onto receivers that collect this solar energy and convert it to heat.

Heat is used for generating hot water or steam. Steam may be used to generate electricity.



U.S. CSP Resource Map



CSP Cost and O&M

CSP Plant Capital Cost Breakdowns (in 2005 $1,000)

	2007 100 MW*
Site Work and Infrastructure	2,455
Solar Field	230,865
HTF System	10,009
Thermal Energy Storage	57,957
Power Block	38,754
Balance of Plant	22,533
Contingency	30,707
Total Direct Costs	**393,280**
Indirects	101,106
Total Installed Cost	**494,386**

Source: NREL Excelergy Model.

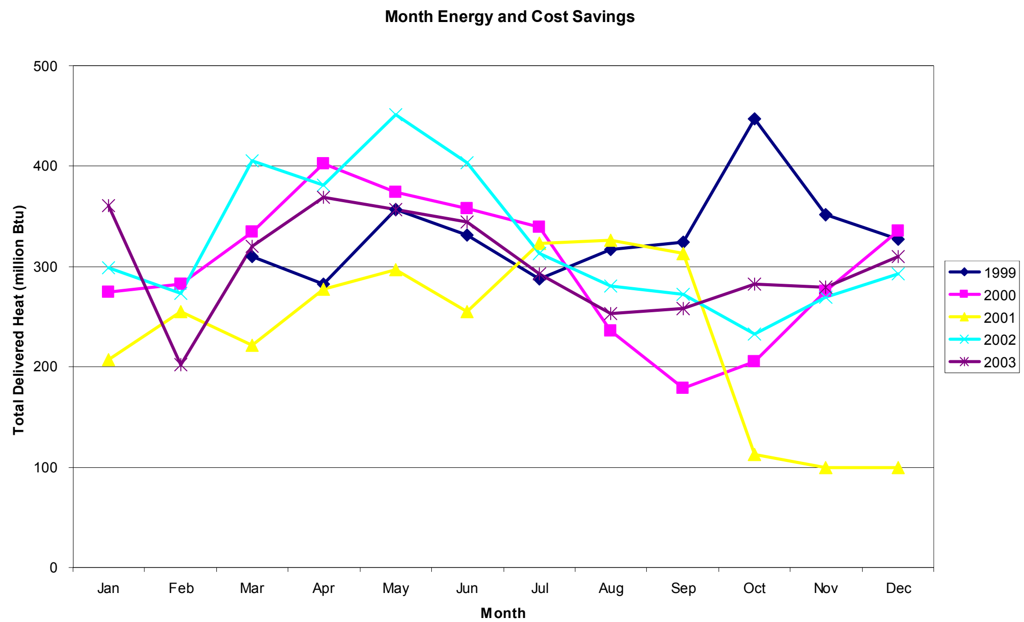
*With 6 hours storage.

Annual CSP O&M Cost Breakdowns (in 2005 $1,000)

	2007 100 MW
Labor	
Administration	528
Operations	979
Maintenance	633
Total Labor	**3,018**
Miscellaneous	419
Service Contracts	263
Water Treatment	260
Spares and Equipment	669
Solar Field Parts and Materials	1,859
Annual Capital Equipment	226
Subtotal	**3,695**
Total	**6,713**

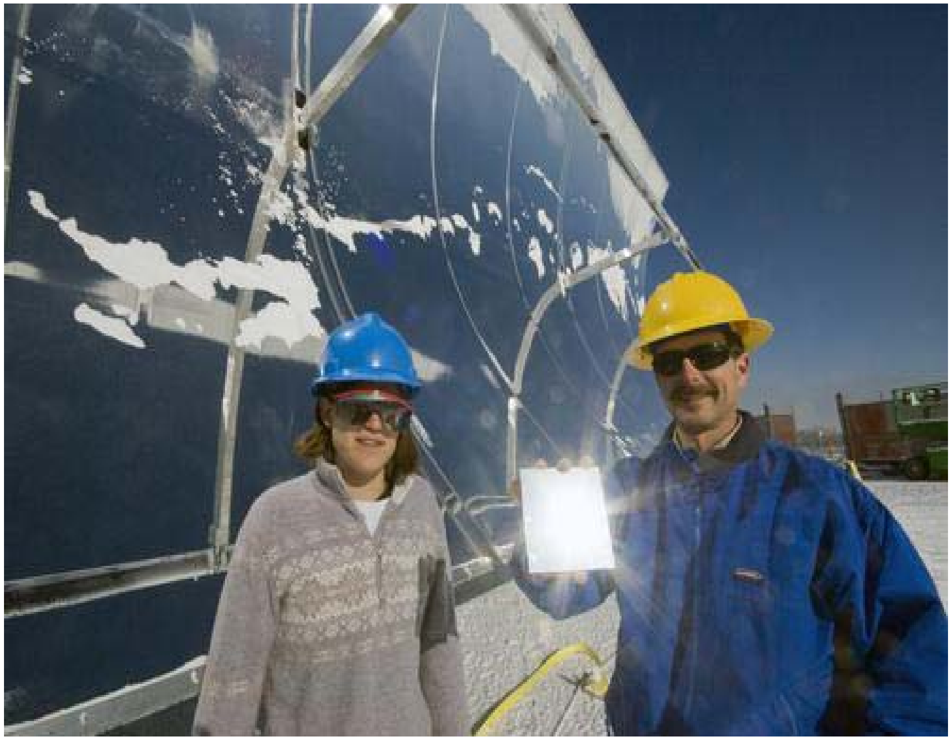
Source: NREL Excelergy Model.

Concentrating Solar Case Study:
Federal Correctional Institution (Phoenix, AZ)



- 17,040 square feet of parabolic trough collectors
- 23,000 gallon storage tank
- Installed cost of $650,000
- Delivered 1,161,803 kWh in 1999 (87.1% of the water heating load).
- Saved $77,805 in 1999 Utility Costs

Horizons of Solar Thermal Research



- Bigger Troughs
- Frame Development
  - fewer parts
  - less weight
  - faster assembly
- Mirror Surfaces
- Direct Steam Generation
- Hybrid Cooling

Wind Power Technologies

Wind Turbine Sizes and Applications

Small (≤10 kW)

- Homes
- Farms
- Remote Applications (e.g. water pumping, telecom sites, icemaking)

Intermediate (10-250 kW)

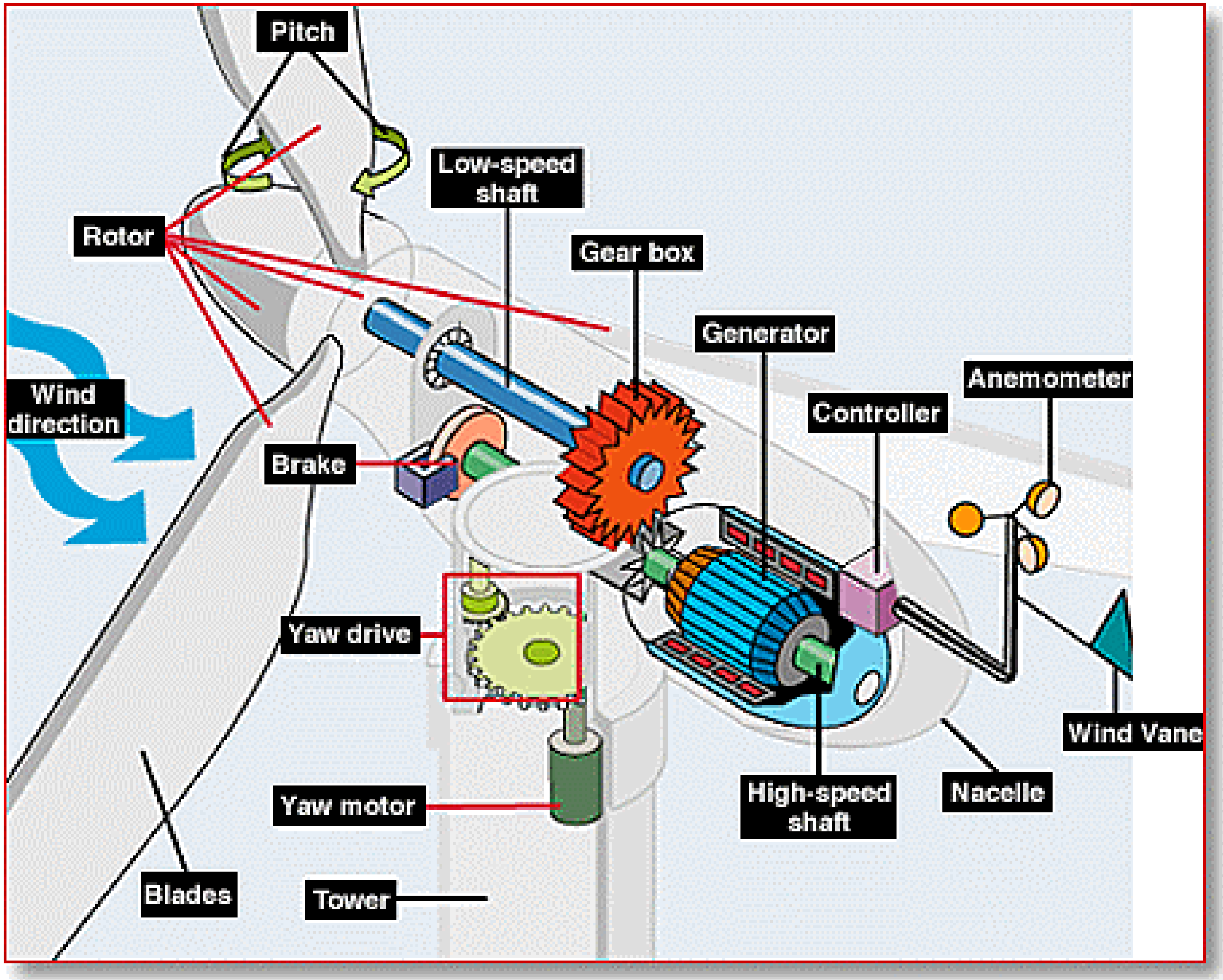
- Village Power
- Hybrid Systems
- Distributed Power

Large (250 kW – 2+ MW)

- Central Station Wind Farms
- Distributed Power

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

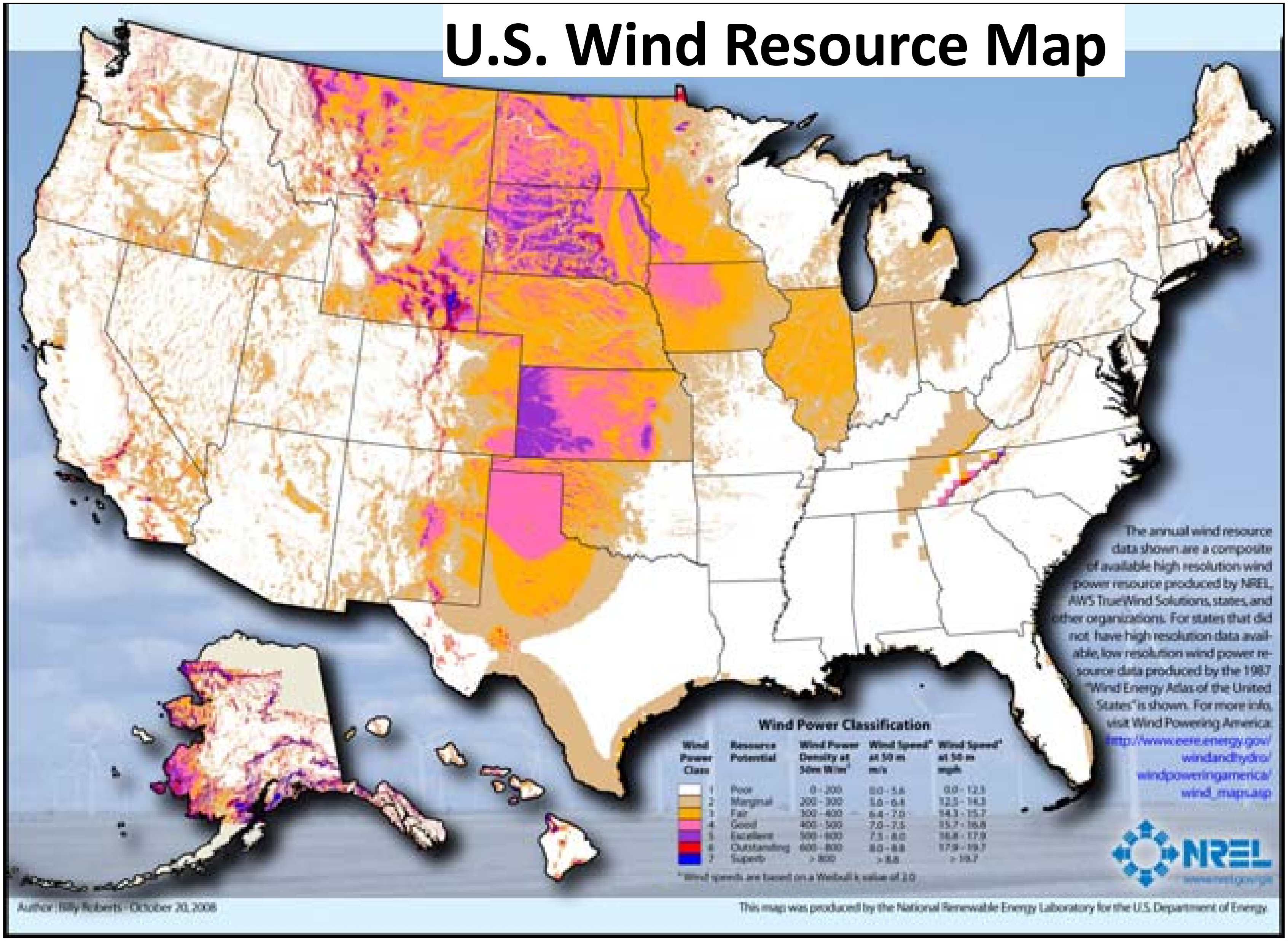
Wind Turbine Components



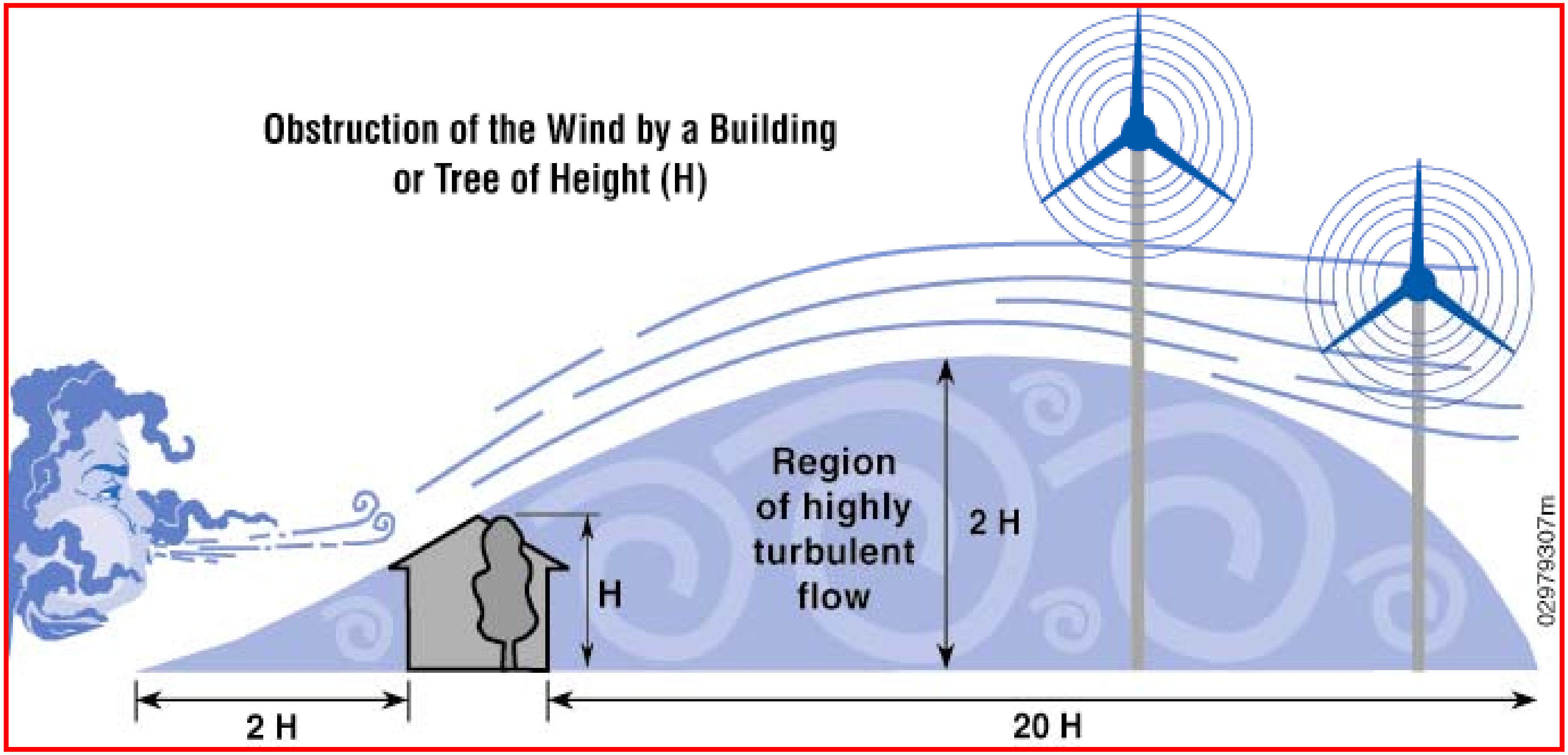
Wind Turbine Technology Overview

- Power output proportional to cube of wind speed
  - 25% higher wind speeds = 2x's the power available
- Wind resource is far more site-specific than solar
- Before investing in large turbines, 50m or taller meteorological (MET) towers are erected to determine site's resource
- MET studies often 1yr or longer

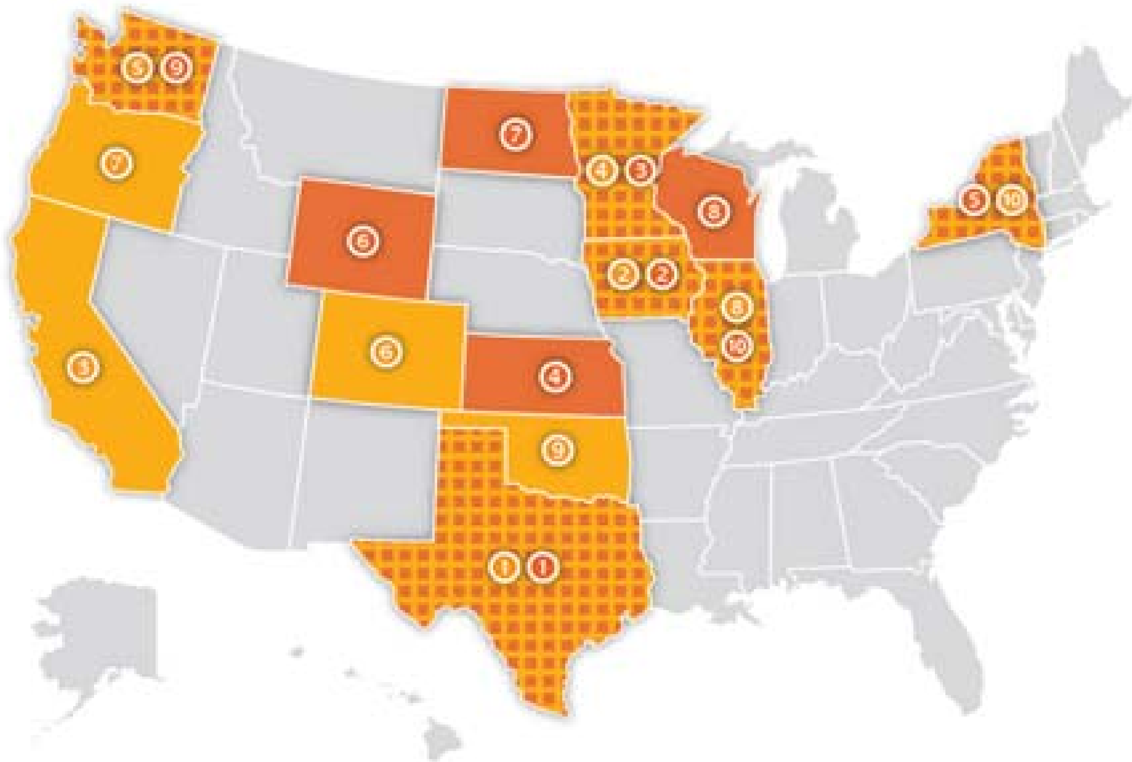
U.S. Wind Resource Map



Importance of "Micro-Siting"



States Leading Wind Power Development

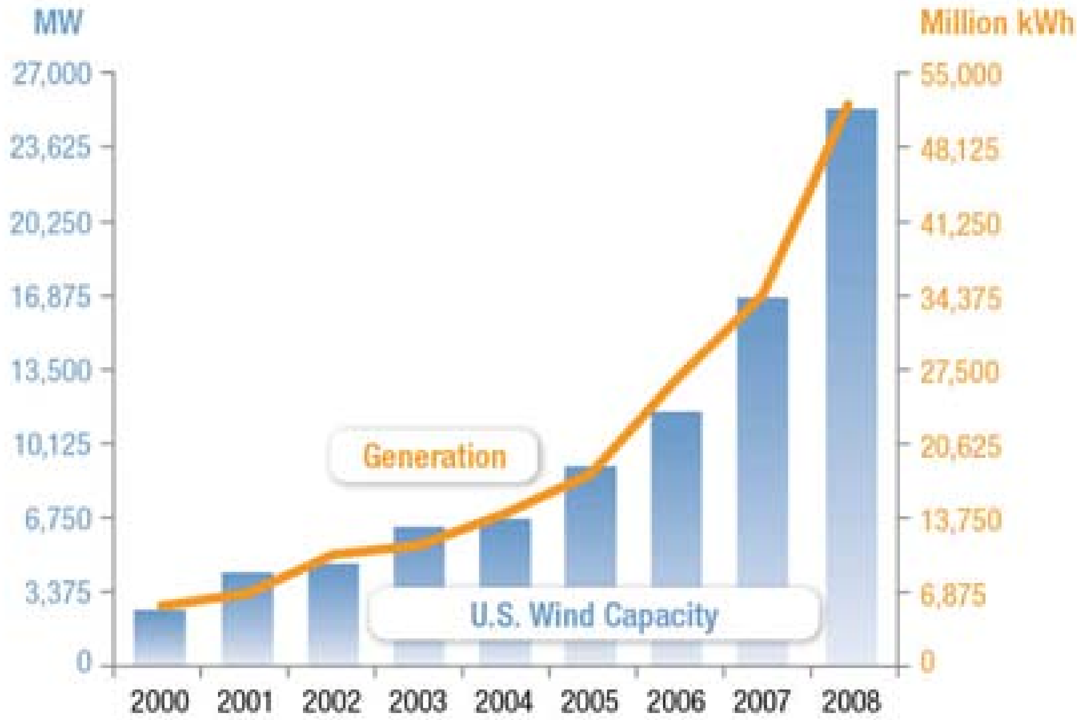


Cumulative Capacity (2008, MW)	
1 Texas	7,118
2 Iowa	2,791
3 California	2,517
4 Minnesota	1,754
5 Washington	1,447
6 Colorado	1,068
7 Oregon	1,067
8 Illinois	915
9 New York	832
10 Oklahoma	831

Annual Capacity (2008, MW)	
1 Texas	2,671
2 Iowa	1,600
3 Minnesota	456
4 Kansas	450
5 New York	407
6 Wyoming	388
7 North Dakota	370
8 Wisconsin	342
9 Washington	284
10 Illinois	216

Source: AWEA

U.S. Total Installed Wind Energy Nameplate Capacity and Generation



	U.S. Wind Energy Generation (Million kWh)	U.S. Wind Energy Capacity and Percent Increase from Previous Year	
		Total (MW)	% Increase
2000	5,593	2,578	2.6%
2001	6,737	4,275	65.8%
2002	10,354	4,686	9.6%
2003	11,187	6,353	35.6%
2004	14,144	6,725	5.9%
2005	17,811	9,121	35.6%
2006	26,589	11,575	26.9%
2007	34,450	16,824	45.3%
2008	52,026	25,369	50.8%

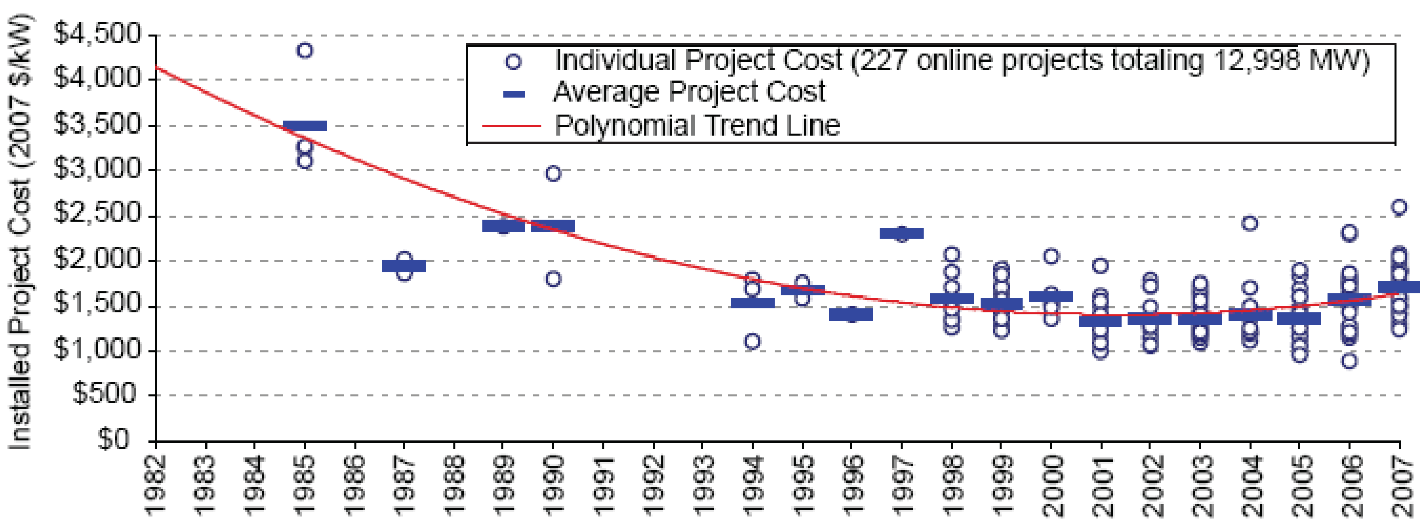
Sources: AWEA, EIA, LBNL

The Cost of Wind Technologies

Installed cost of wind technology has almost doubled since 2005 due to:

- Increasing cost of materials (copper, steel and concrete)
- Exchange rate due to weak dollar
- Market demand
- Increasing implementation costs

Wind technology at windy locations is still cost competitive with any new power generation – though economics differ by site



Source: Berkeley Lab database (some data points suppressed to protect confidentiality).

Installed Wind Project Costs Over Time

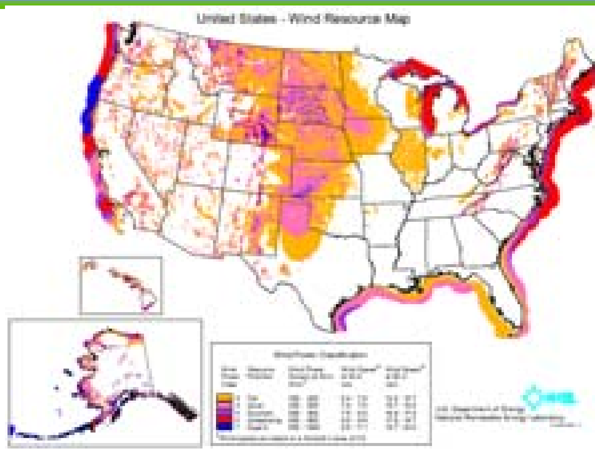
Wind Power Case Study:
Warren Air Force Base (Cheyenne, WY)

660 kW wind turbines

- Cost $2.5 million installed
- Generate enough clean energy to power 522 households on the base
- Avoids producing 5,000 tons/year of carbon dioxide emissions
- Will save $3 million in energy costs over 20 years

Adding 2 MW turbine for toal of 3.3 MW and 9,251,000 kWh/year

Horizons in Wind Energy



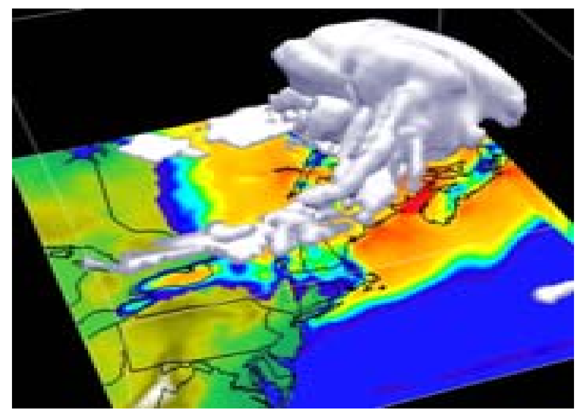
US Wind Resource Exceeds Total Electrical Demand

Offshore Wind

Advanced Blades

Innovative Tall Towers

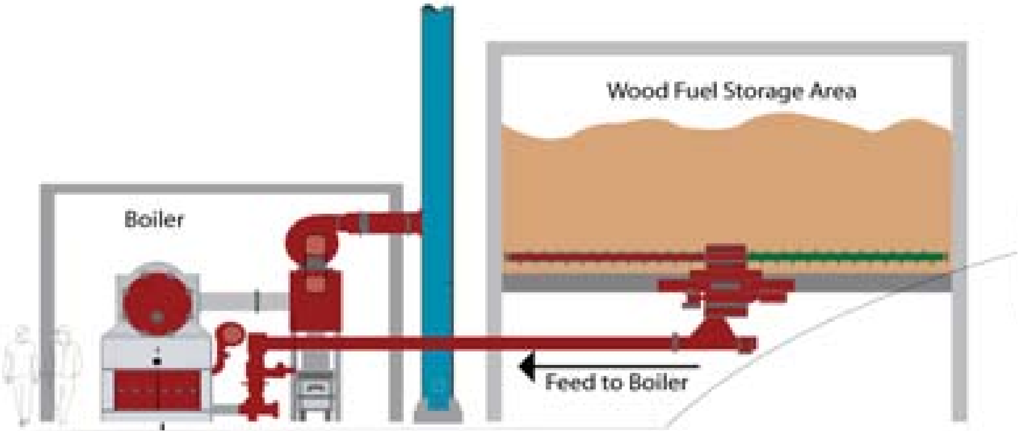
Giant Multi-megawatt Turbines



Courtesy:WindLogics, Inc. St. Paul, MN

Wind Forecasting

Biomass

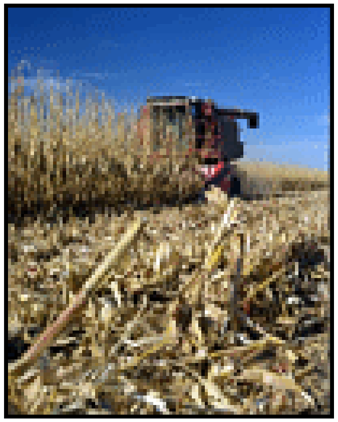


Biomass Feedstocks

Forest Wood Residues

Thinning residues
Wood chips
Urban wood waste
- pallets
- crate discards
- wood yard trimmings

Agricultural Residues



Corn stover
Rice hulls
Sugarcane bagasse
Animal biosolids

Energy Crops

Hybrid poplar
Switchgrass
Willow

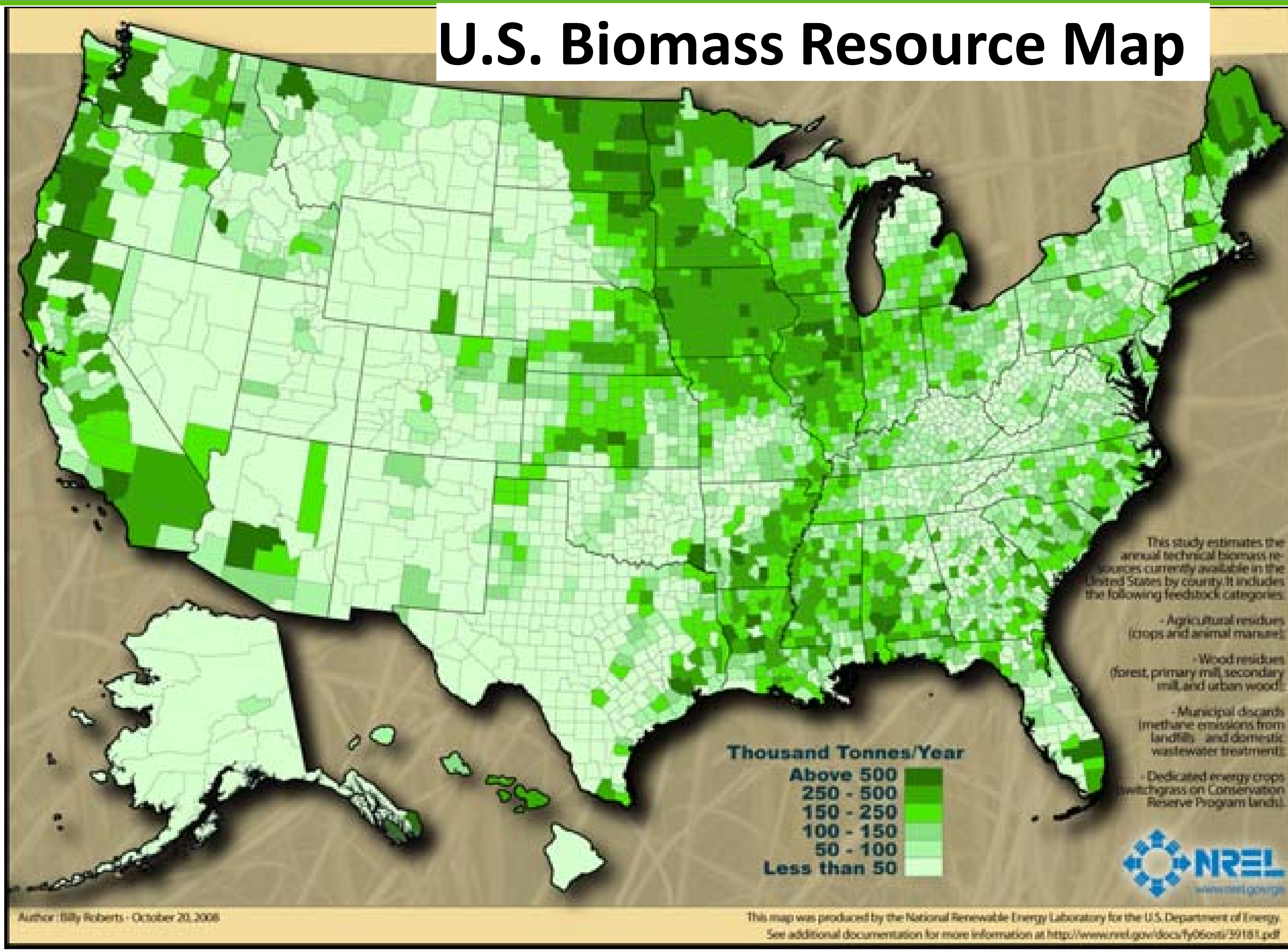
Biomass Technology Overview

Resource		Conversion Option	Technology Type
Solid Biomass	• Wood • Wood waste • Agricultural residues • Bagasse • Food processing residues • Animal wastes • Municipal Solid Waste (MSW) • Energy crops	Direct Combustion	Biomass-only Rankine (steam) Cycle
			Co-firing Rankine Cycle (primarily coal)
		Gasification	Biomass-only Rankine Cycle
			Biomass-only GT/IGCC
			Biomass-only IC Engine (ICE)
			Co-firing (coal or NG Rankine, IGCC, CCGT)
			Co-gasification of biomass and coal
		Liquefaction (Pyrolysis)	Biomass-only (Rankine, GT, ICE)
			Co-firing (Rankine, GT/GTCC, ICE)
Gaseous Biomass (biogas)	• Landfill gas • Methane from waste & wastewater treatment	Direct Combustion/ Conversion	Biomass-only Rankine Cycle
			Biomass-only GT, GTCC, ICE
			Biomass-only Fuel Cell

Note: GT = gas turbine, GTCC = gas turbine combined cycle; IGCC = integrated gasification combined cycle, ICE = internal combustion engine.

- National goals
  - Reduce gasoline usage by 20% in ten years
  - New feedstocks
  - Integrated biorefineries

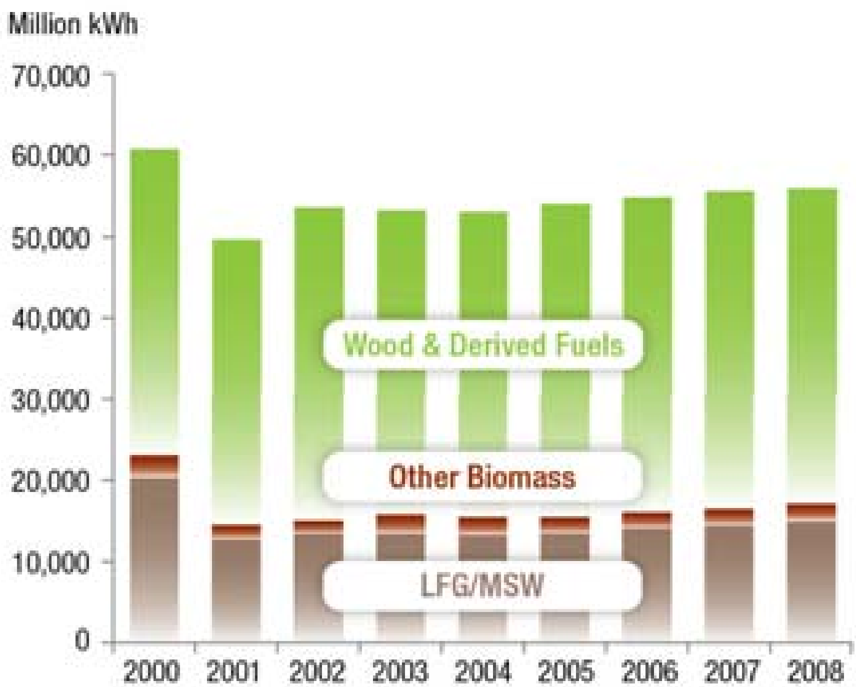
U.S. Biomass Resource Map



Biomass Costs, Installed Capacities, and Efficiencies

Technology	Installed Capacity (MW)	Power Range (MW)	Cost per kW (K$)	Power Efficiency (%)
Direct Combustion Co-Firing	7800	2 - 100	1 - 1.5	20 - 25
Gasification	1500	5 - 50	1.8 – 2.0	30 - 40
Diesel & IC	650	0.2 - 5	0.7 - 1.5	25 - 35
Microturbines	N/A	.03 -0 .25	2.0	20 - 30
Fuel Cells	N/A	5 - 250	5.0	30 - 50

U.S. Biopower Generation Sources (2000–2008)



	LFG/MSW	Other Biomass	Wood and Derived Fuel	TOTAL
2000	20,305	2,826	37,595	60,726
2001	12,714	1,834	35,200	49,748
2002	13,398	1,646	38,665	53,709
2003	13,383	2,428	37,529	53,340
2004	13,281	2,216	37,576	53,073
2005	13,470	2,009	38,681	54,160
2006	14,106	2,004	38,649	54,759
2007	14,462	2,063	39,014	55,539
2008	14,953	2,133	38,789	55,875

Source: EIA

Note: LFG stands for Landfill Gas and MSW stands for Municipal Solid Waste

Note: The generation decrease between 2000 to 2001 reflects an EIA classification change. Beginning with 2001 data, non-biogenic Municipal Solid Waste and tire-derived fuels were reclassified as non-renewable energy sources (previously considered waste biopower).

NREL Renewable Fuels Heating Plant

$3.3 million cost

pine beetle epidemic and waste wood from A-1 Organics

75 percent of the 50,000 million Btus to heat the STM campus.

Energy Savings Performance Contract with Ameresco

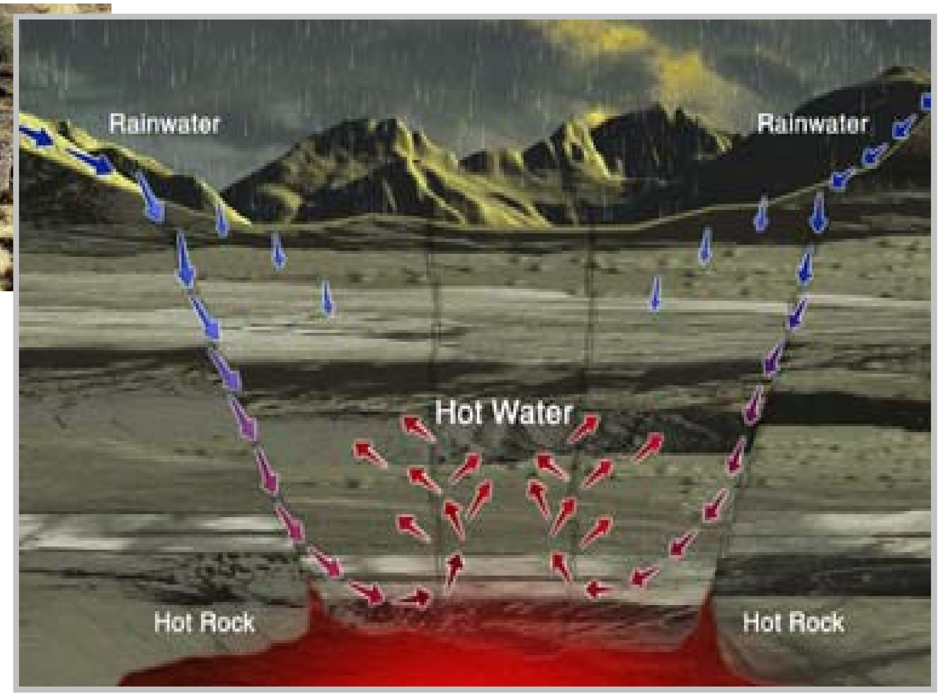
Cost savings projected $400,000/year

The wood chips cost $29 per ton or $2.42 per million BTUs — about one-quarter of the cost of natural gas.

During cold weather, the plant burns a truckload of wood chips per day and produce 600 gallons of hot water per minute. 3,600 tons of wood chips in a year.

Stores four days of wood chip fuel.

Geothermal Energy



Geothermal Energy Technology Overview

Application opportunities include:

- Direct Use - Using hot water from springs or reservoirs near the surface.
- Electricity generation – Using steam, heat or hot water from deep inside the earth to drive turbines.
- Geothermal heat pumps – Using the earth, groundwater, or surface water as a heat source and heat sink

Geothermal Status and Goals

Today's Status in U.S.

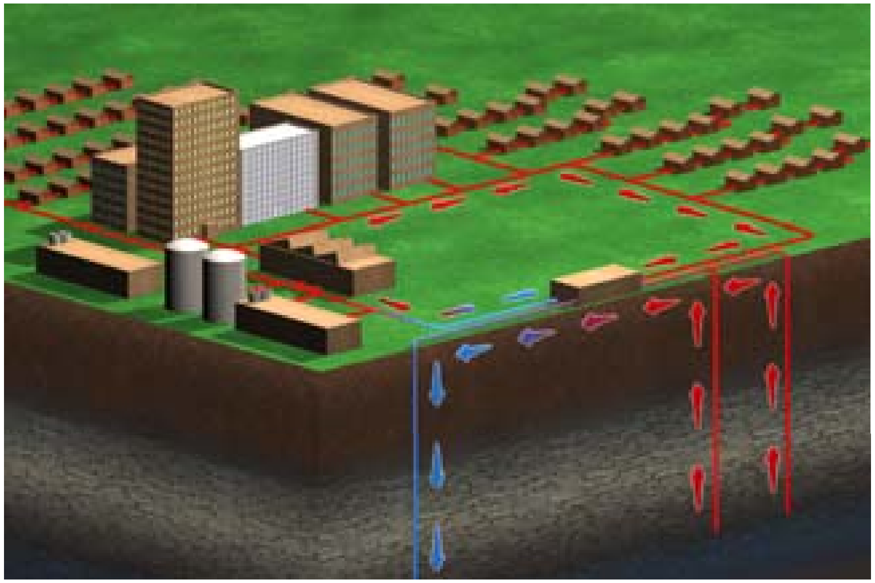
- 2,800 MWe installed, 500 MWe new contracts, 3000 MWe under development
- Cost 5-8¢/kWh with no PTC
- Capacity factor typically > 90%, base load power

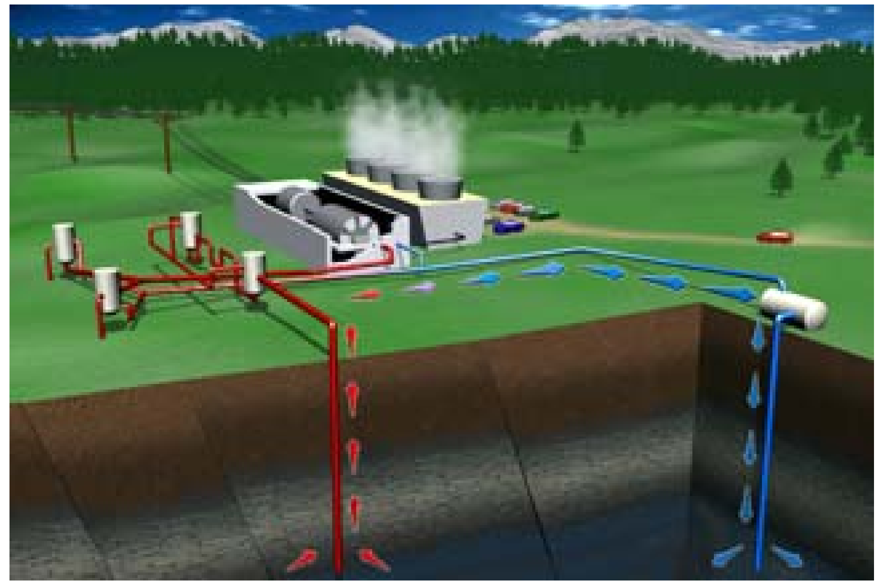
DOE Cost Goals:

- <5¢/kWh, for typical hydrothermal sites
- 5¢/kWh, for enhanced geothermal systems with mature technology

Long Term Potential:

- Recent MIT Analysis shows potential for 100,000 MW installed Enhanced Geothermal Power systems by 2050, cost-competitive with coal-powered generation



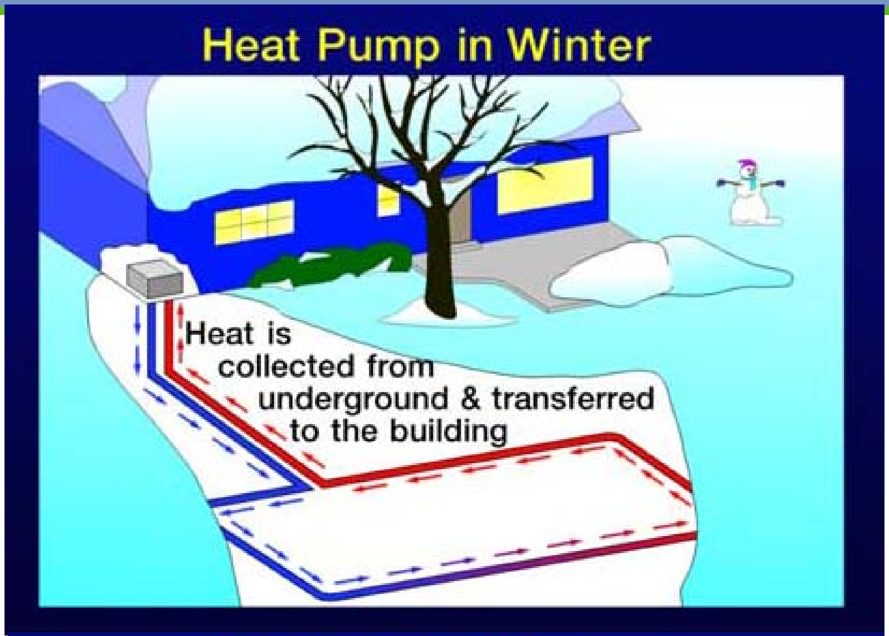


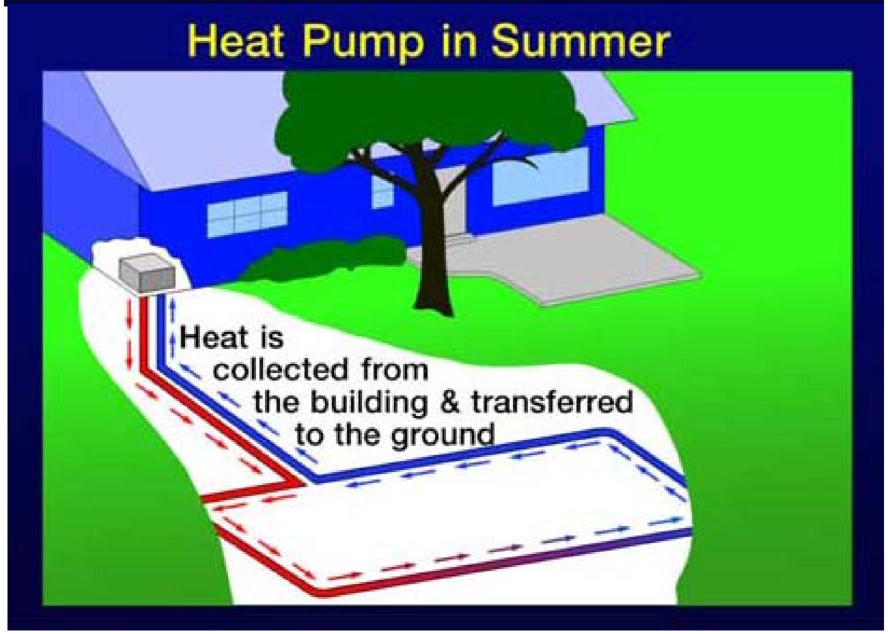
Heat Production

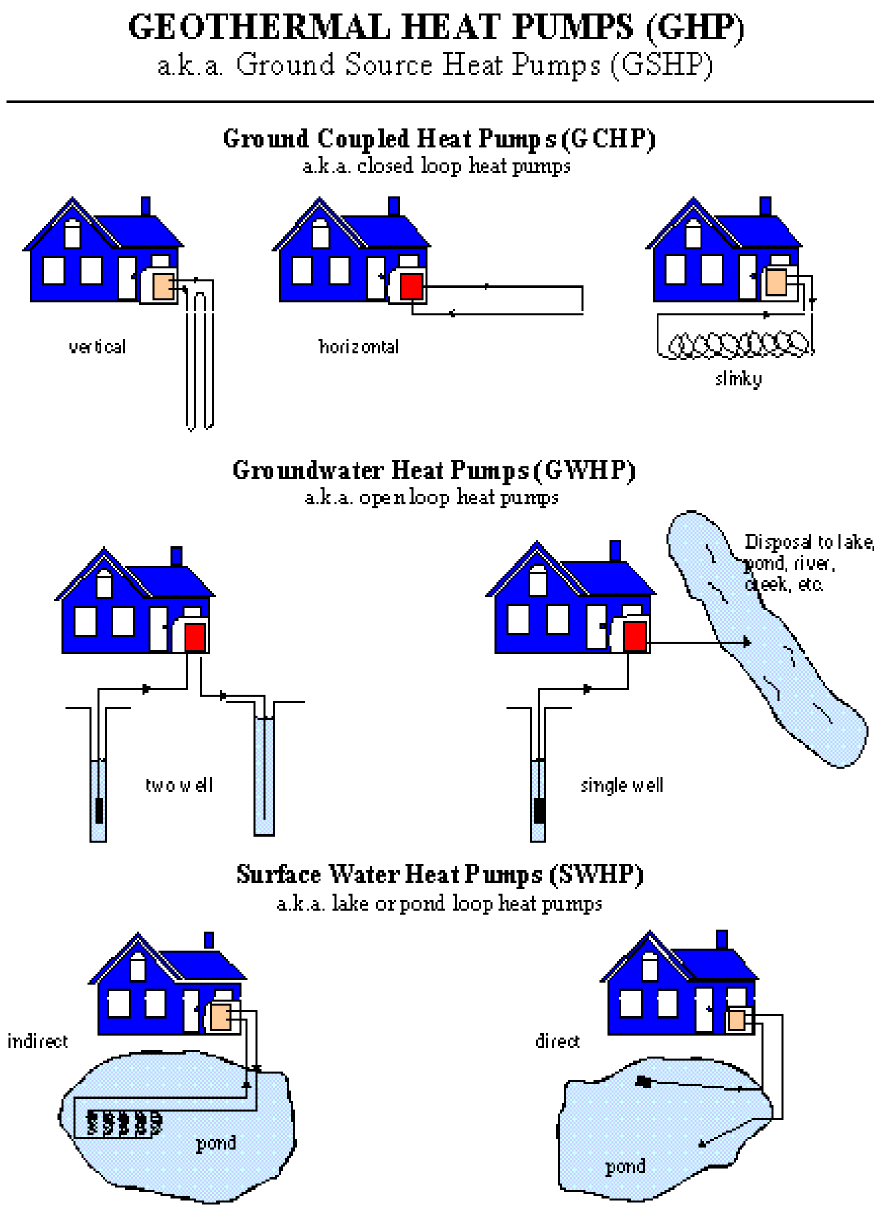
- District Heating
- Process Heat
- Agriculture
- Aquaculture

Electricity Generation

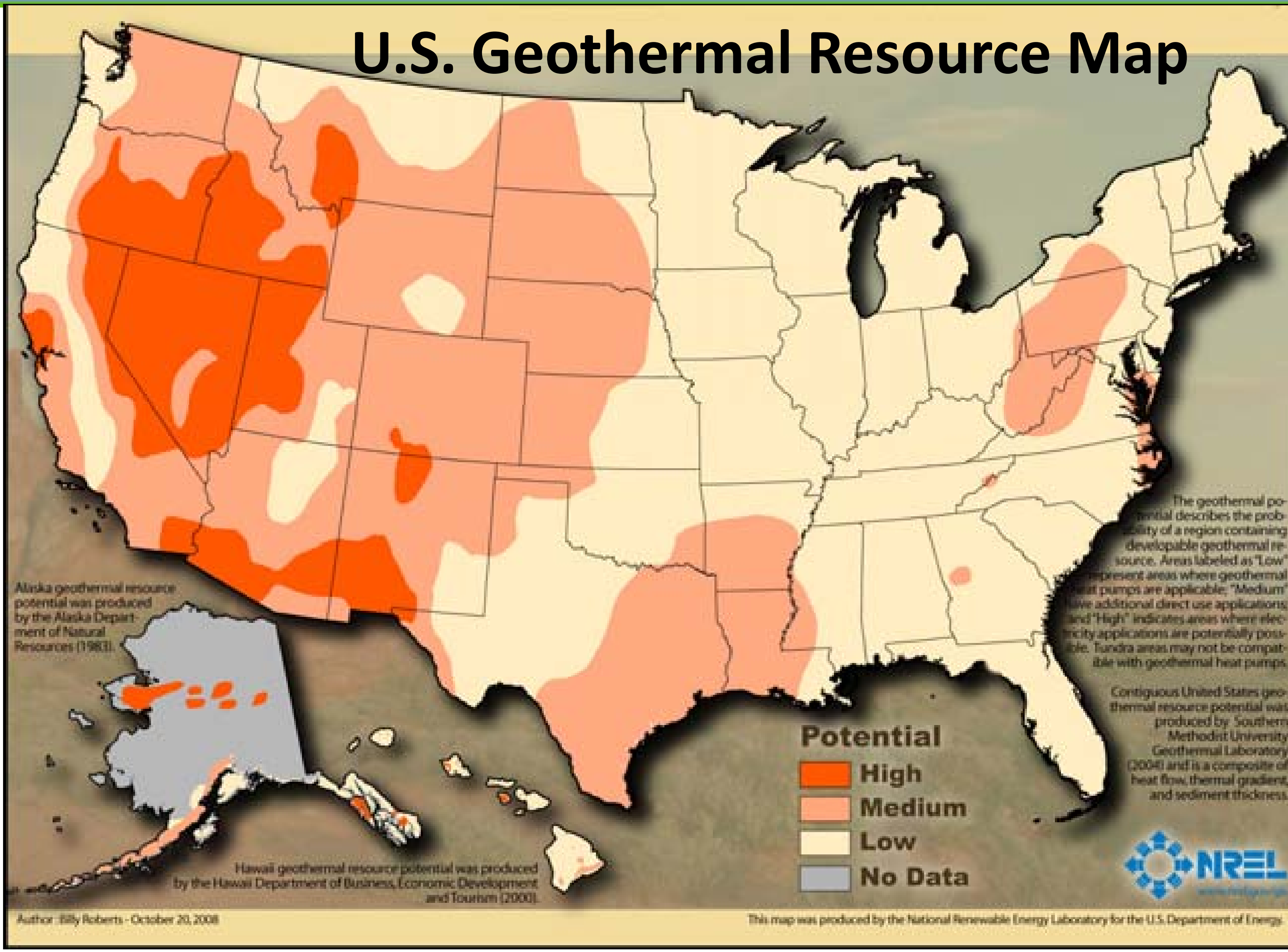
- Distributed Power
- Central Station Power


Heat Pump in Winter
Heat is collected from underground & transferred to the building


Heat Pump in Summer
Heat is collected from the building & transferred to the ground


GEOTHERMAL HEAT PUMPS (GHP)
a.k.a. Ground Source Heat Pumps (GSHP)
Ground Coupled Heat Pumps (GCHP)
a.k.a. closed loop heat pumps
vertical
horizontal
slinky
Groundwater Heat Pumps (GWHP)
a.k.a. open loop heat pumps
Disposal to lake, pond, river, creek, etc.
two well
single well
Surface Water Heat Pumps (SWHP)
a.k.a. lake or pond loop heat pumps
indirect
pond
direct
pond

U.S. Geothermal Resource Map



Geothermal Costs

Application	Costs	Reference
GHP	\$2500/ton of capacity + \$1000-3000/ton for trenching (residential sizes)	http://www.wapa.gov/es/pubs/fctsheet/GHP.pdf
Direct Geothermal	\$330/kbtu/hr, Dependent on: • spring source or wells • resource temperature • distance • type of technology (e.g. direct use, as in a swimming pool, or requiring piping/heat exchangers/inside pumps, blowers, etc.)	FEMP Study for USFS Lucky Peak Nursery, December 16, 2005
Geothermal Power	\$2500-\$5000/kWe	http://www1.eere.energy.gov/geothermal/faqs.html

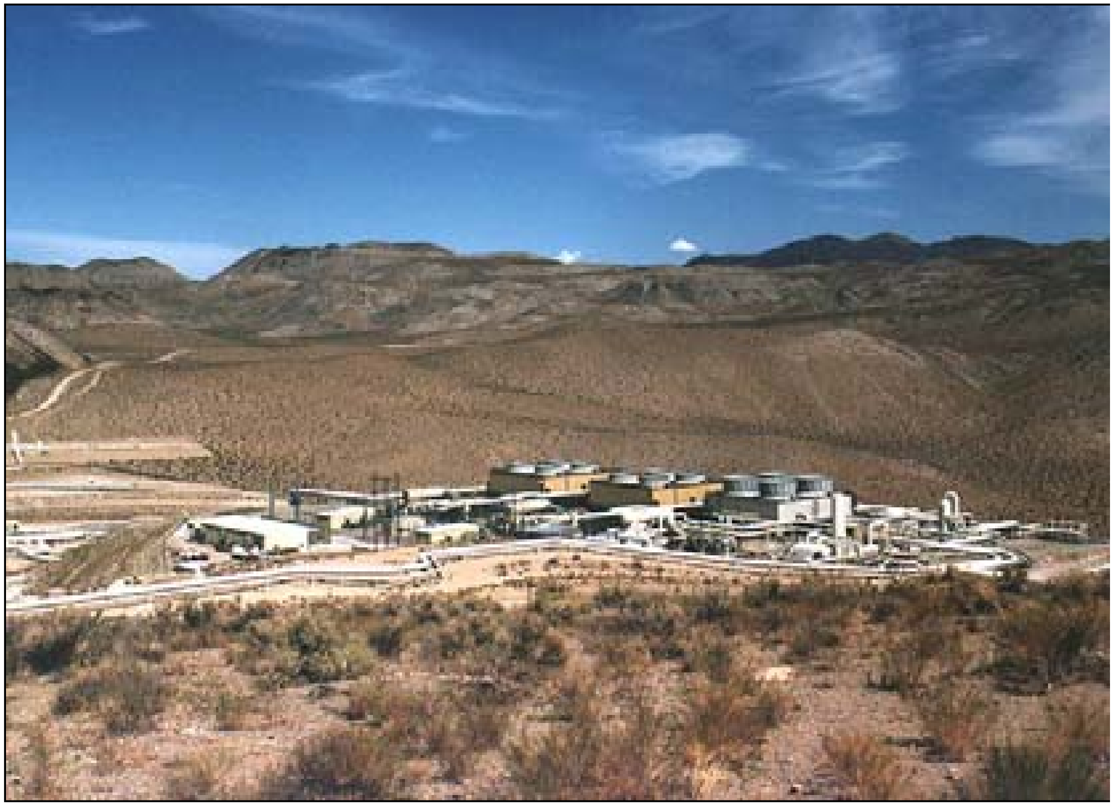
Worldwide Geothermal Installed Capacity

Type of Application	Installed Capacity	Date of Study	Reference
GHP	15,384 MWth	June-05	http://www.worldenergy.org/publications/survey_of_energy_resources_2007/geothermal_energy/736.asp
Direct Geothermal	16,000 MWth	September-07	http://www.bv.com/resources/energy_brochures/renewables/rsrc_AZ_RenewableEnergyAssessment.pdf
Geothermal Power	8,900 Mwe	September-07	http://www.bv.com/resources/energy_brochures/renewables/rsrc_AZ_RenewableEnergyAssessment.pdf

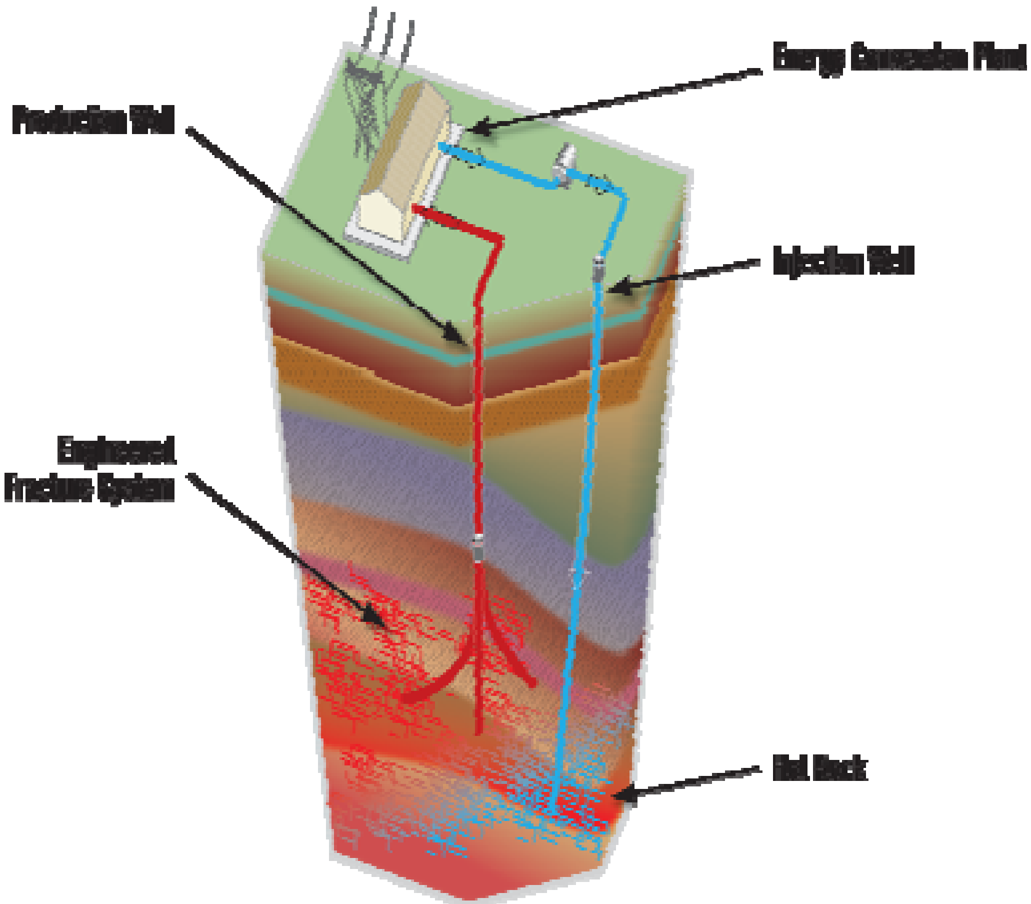
Geothermal Case Study:
Coso Geothermal, US Navy, China Lake CA

- Four power plants – 2 Navy & 2 BLM
- Nine turbine-generator sets
- 270 MW Max net output
- Two transmission lines
- 166 wells
- Enough power to supply electricity to 180,000 homes

- Others: NAS Fallon NV (30 MW, awarded 2005); Army Hawthorne, NV; Navy El Centro, 29 Palms and Chocolate Mtns, CA



Horizons of Geothermal Research



- Engineering below-ground systems.
- pathways to commercialization
- Systems engineering/integration
- Geothermal energy conversion RD&D
- Low temperature geothermal, direct use
- Ground source heat pump RD&D
- Dry cooling and hybrid cooling

Source: NREL

Ocean Energy

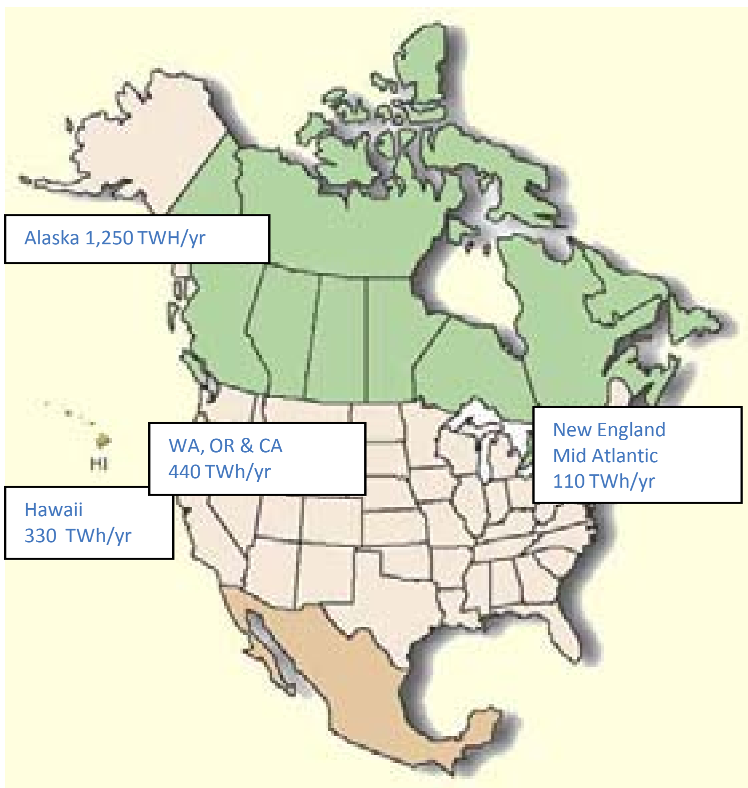
- Seemingly ‘limitless’ power source
  - Think pounding surf, hurricane energy
- Technically challenging
  - Think pounding surf, hurricane energy
- Technology is relatively immature
  - Current project count in the tens
  - No general rules of thumb on installation and O&M costs

Ocean Energy Technologies

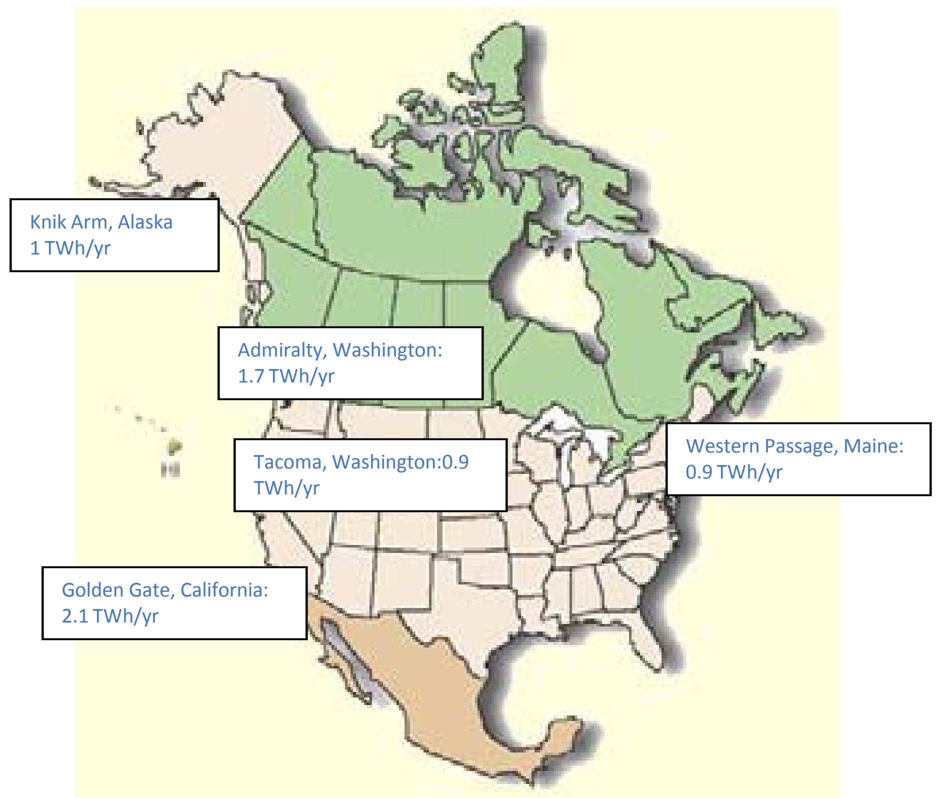
- Wave power
- Marine current power
  - Marine current moves continuously
- Tidal Energy
  - Oscillates or dams water from high tides
- Ocean Thermal Energy Conversion (OTEC)

Ocean Energy Resources

The U.S. wave and current energy resource potential that could be harnessed is about 400 TWh/yr



Estimate Wave Energy Resource in U.S.



Estimate Tidal Current Energy Resource in U.S.

Passive Solar and Daylighting

Rely on proper site orientation, building envelope design, window placement, construction materials

Passive Solar

- Part of building's design, not usually a retrofit
- Building absorbs solar energy for heat needs
- Added thermal mass to absorb daily heat and release at night
- Controls such as operable shades and windows

- For building areas with little or no internal heat gain.

Passive Solar Heating

Direct Gain

TTF Facility, NREL

Sunspace

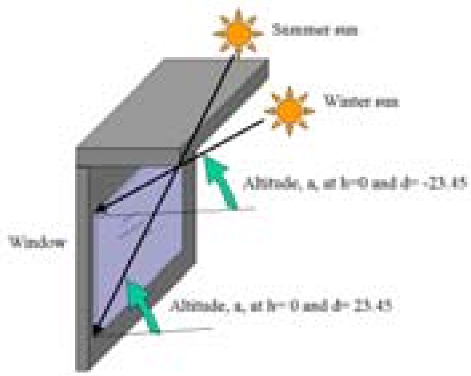
SERF, NREL

Trombe Wall (Thermal Storage Wall)

SERF, NREL

Cooling Load Avoidance

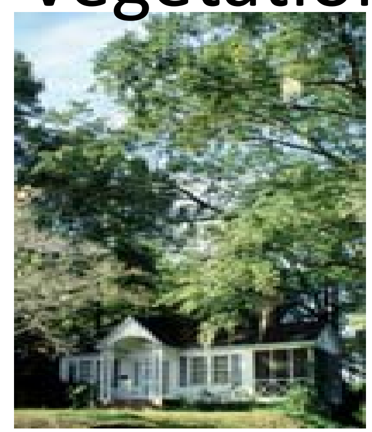
South Side Overhangs



Silver Hill Office Building, Golden CO

Glazing Properties

Vegetation



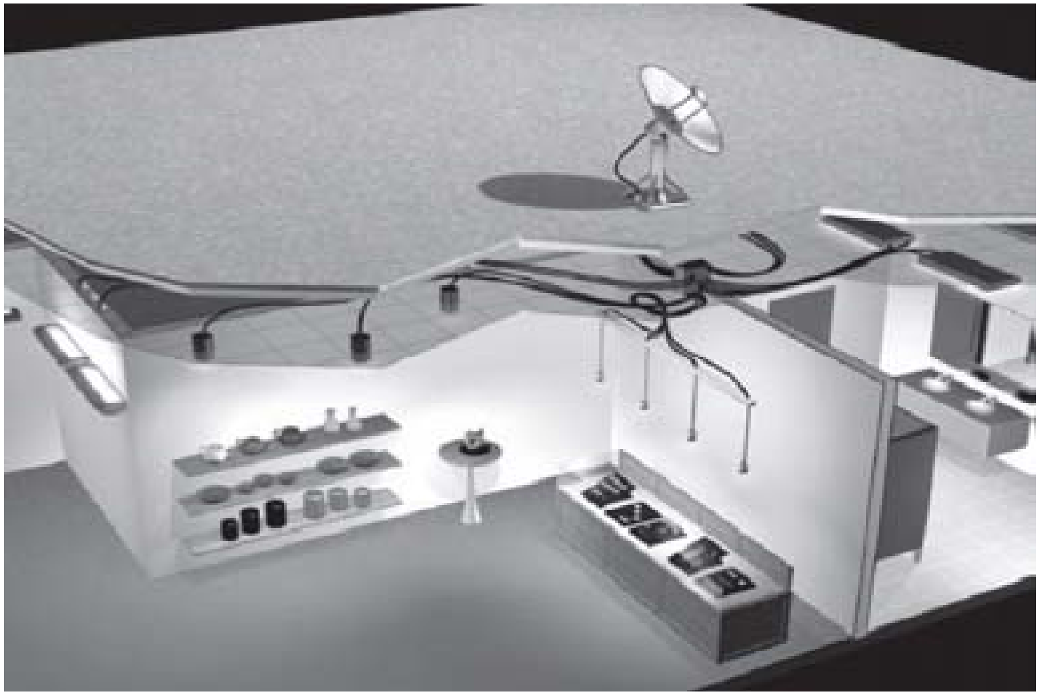
Cool Roof

Daylighting

- Lighting accounts for 25% of the total electricity used in the federal sector
- Lighting accounts for more than a third of all electricity consumed for commercial use in the US
- Heat from lighting adds to building cooling loads
- Daylighting uses windows & skylights in conjunction with automatic light controls to minimize the need for electric lighting during daylight hours
- Daylighting combined with lighting controls can reduce lightingenergy consumption by 40 - 60%
- Average skylight cost is between $500 - $1,200

Emerging Technologies: Hybrid Solar Lighting

- Roof-mounted solar collector concentrates visible sunlight into a bundle of plastic optical fibers
- The optical fibers distribute the sunlight to multiple “hybrid” luminaires, which blend the natural light with artificial light
- One collector powers about eight fluorescent hybrid light fixtures, which can illuminate about 1000 square feet



Daylighting

Skylights

Soluminaire

Durant Middle School
North Carolina

Light Shelves

Roof Monitor

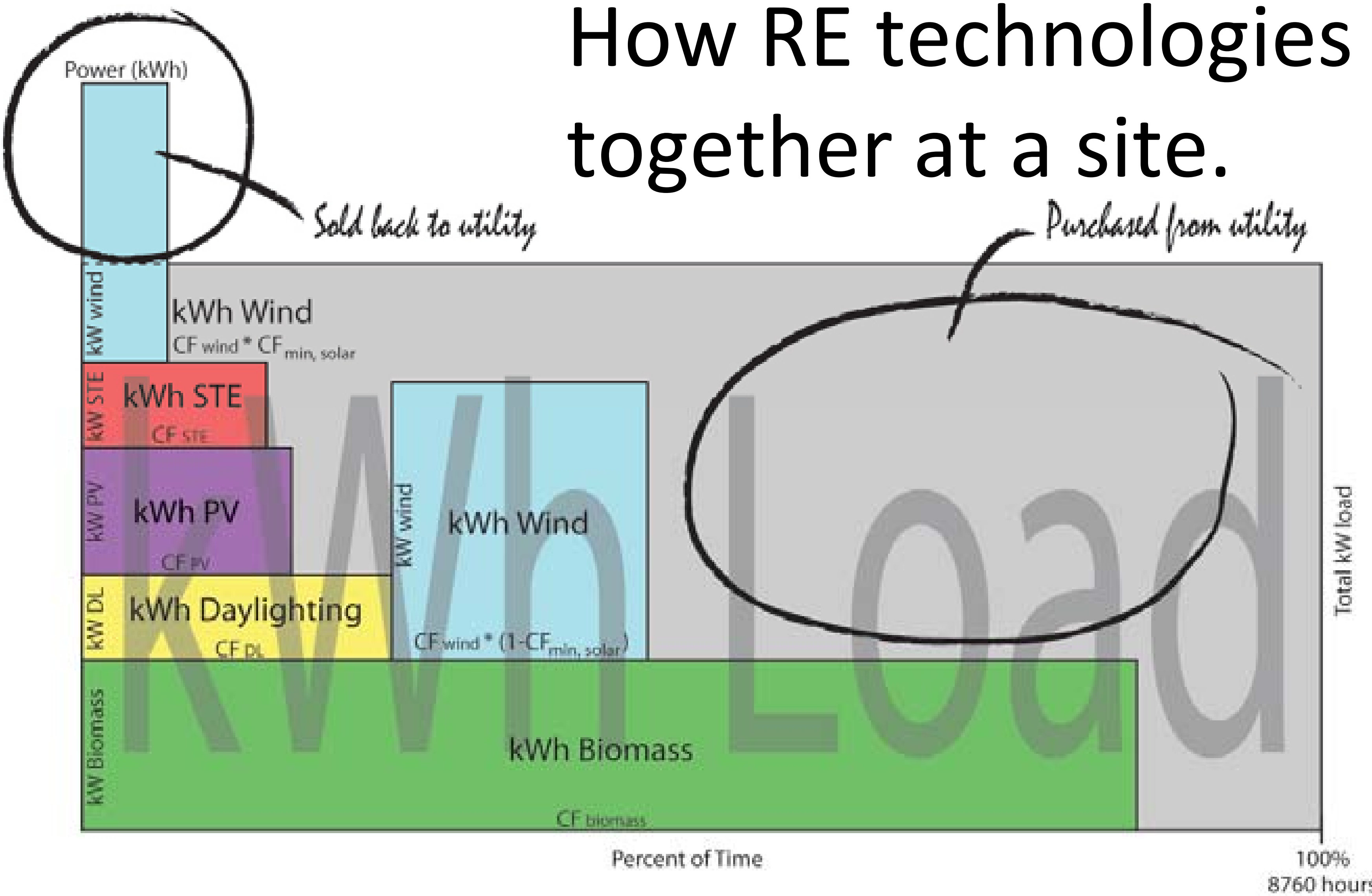
Bighorn Home Improvement
Center, Silverthorne CO

Controls

Fitting It All Together

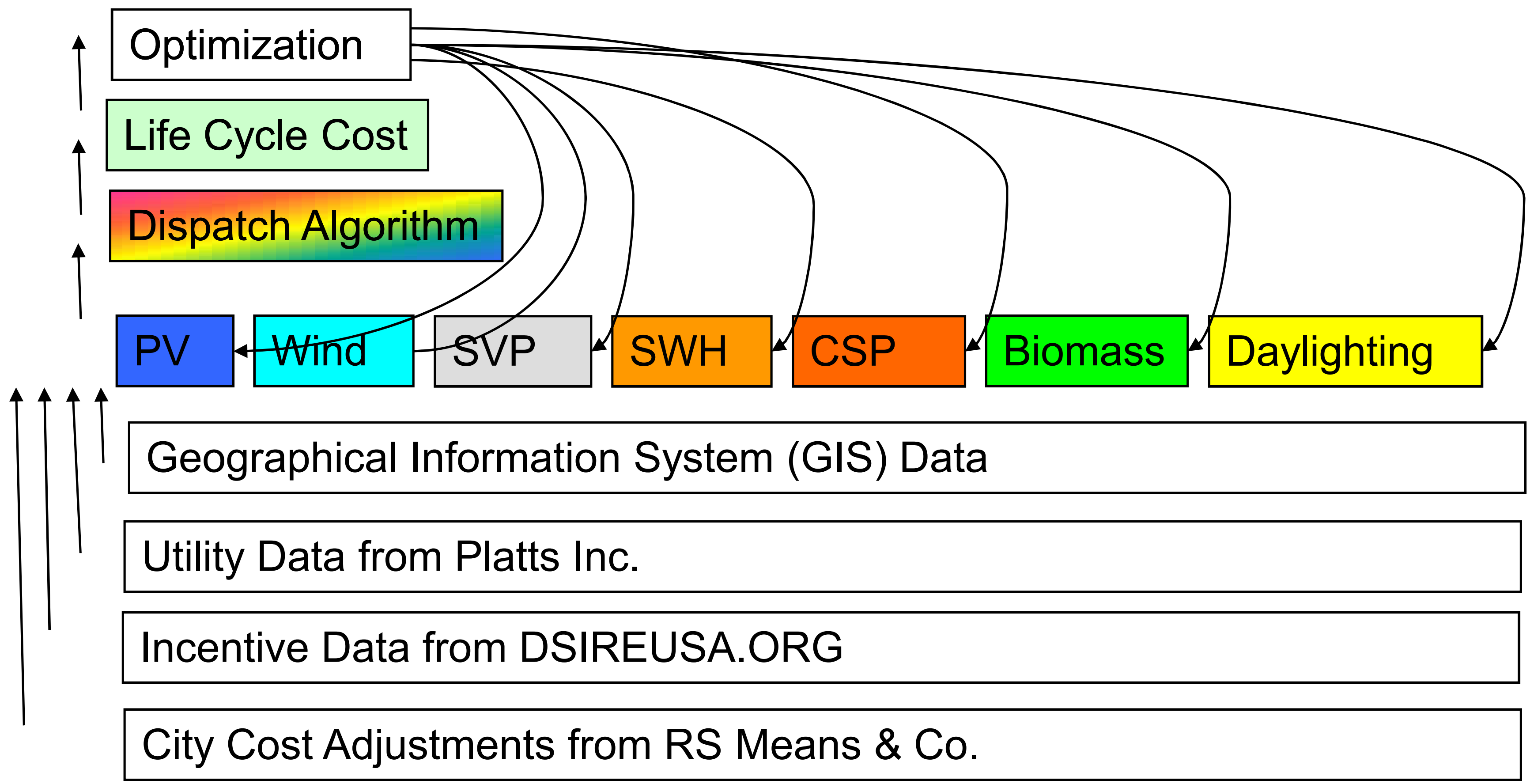
- Optimal solution often includes
  - Energy efficiency measures
  - Multiple technologies
  - Conventional resources (gas, electric)
- Approach: REO Analysis Tool

How RE technologies fit together at a site.

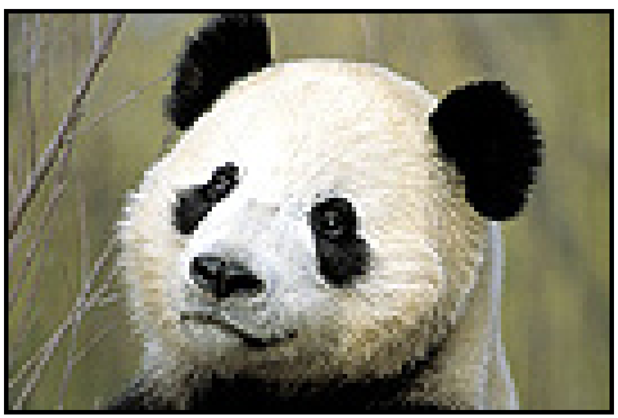


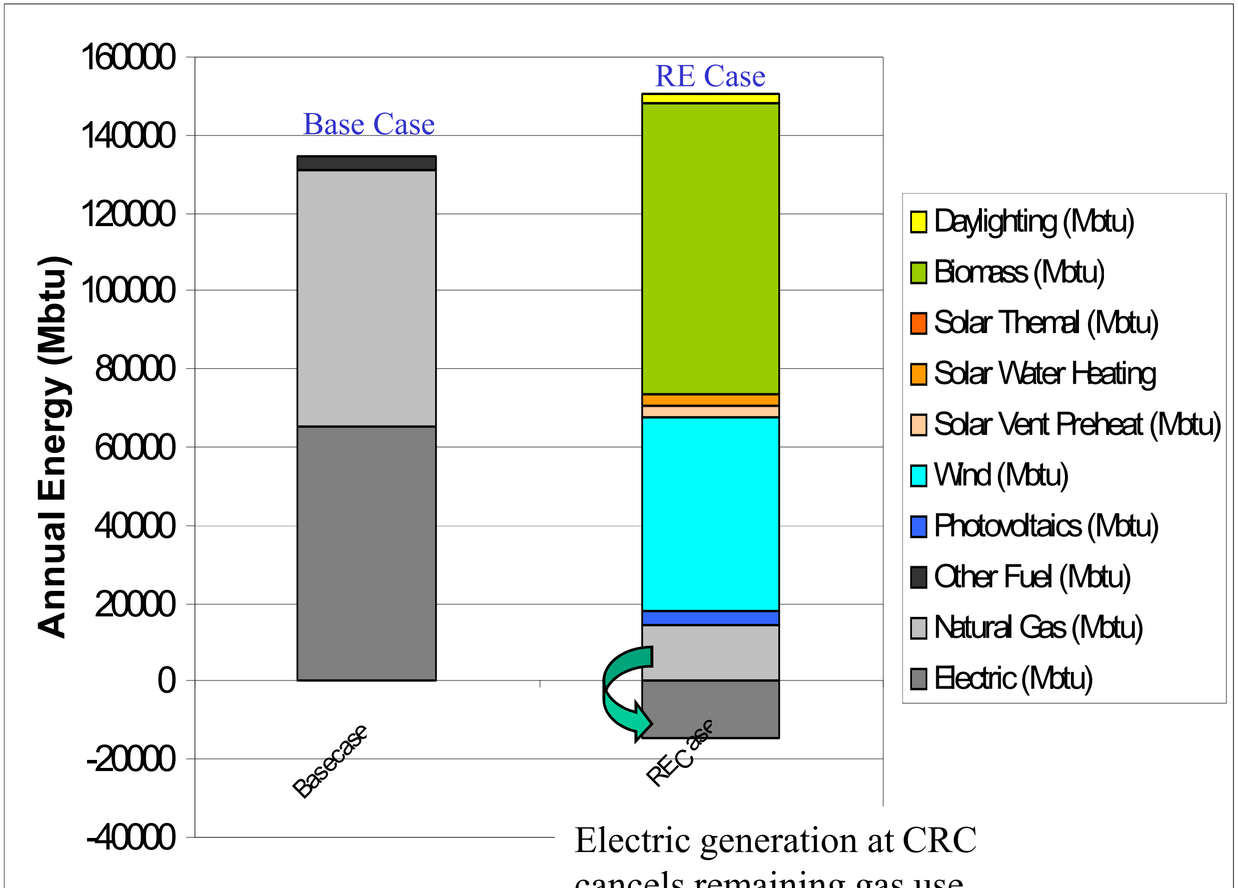
For "Net Zero", sold back to utility must equal purchased from utility

RE Optimization Procedure



REO Example: Net Zero Zoo, National Zoological Park (NZP) and Conservation Research Center (CRC)





Zoo Entrance
Tai Shan the Panda

Electric generation at CRC cancels remaining gas use at NZP

Financial Strategies

- Appropriations
- Energy Savings Performance Contracts (ESPC)
- Power Purchase Agreements (PPA)
- Enhanced Use Lease
- Utility Energy Service Contracts (UESC)

Requirements for Success

- Appropriate Application (Provide a Reasonable Payback)
- Proven Design
- Redundant Freeze Protection
- Properly Sized (undersized, not oversized)
- Require No Manual Intervention
- Operational Indicators or Monitoring
- Conservation First
- Verify Load
- Performance Guarantee
- Require Operations and Maintenance Manual and Training
- Acceptance Test

Information Resources

- Tester, et al., *Sustainable Energy: Choosing Among Options*
- PV: http://www1.eere.energy.gov/solar/photovoltaics.html
- Solar Heating: http://www1.eere.energy.gov/solar/solar_heating.html
- Solar Ventilation Preheat: http://www1.eere.energy.gov/femp/technologies/renewable_svp.html
- Concentrated Solar: http://www1.eere.energy.gov/solar/csp.html
- Wind Power: http://www1.eere.energy.gov/windandhydro/wind_technologies.html
- Biomass: http://www1.eere.energy.gov/biomass/